PE- 66

US Army Corps
of Engineers
Portland District

Mount St. Helens, Washington
DECISION DOCUMENT

Toutle, Cowlitz and Columbia Rivers

October 1985

Report Documentation Page

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ERRATA

MOUNT ST. HELENS DECISION DOCUMENT

Please note that the total estimated Real Estate Costs for the 125-foot spillway SRS is $9.8 million as shown int Table III-6. The $12.2 million figure shown in Tables IV-14, B-9 and B-11 is incorrect.

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, DC 20310-0103

October 15, 1985

Honorable James C. Miller III
Director
Office of Management and Budget
Washington, D. C. 20503

Dear Mr. Miller:

On May 10, 1985, I submitted a copy of the report of the Chief of Engineers and accompanying supplement on Mount St. Helens Sediment Control, Washington (Toutle, Cowlitz, and Columbia Rivers). In my submittal letter I advised, in part, as follows:

> The Corps [of Engineers] is proceeding with CP&E [continuation of planning and engineering] studies. The objective of CP&E is to develop additional information on the sediment problem and the benefits and costs of alternative solutions. A final selection will be made at the Washington level next fall. We will coordinate with your office on the selection of the alternative that will be carried into final design.

In fulfillment of the commitment made last spring, I am submitting a copy of a memorandum of the Chief of Engineers on Mount St. Helens, Washington (Toutle, Cowlitz, and Columbia Rivers), together with the Mount St. Helens Decision Document, dated October 1985, prepared by the Portland District, North Pacific Division, Army Corps of Engineers. In his memorandum, the Chief of Engineers has affirmed his April 3, 1985, recommendation for implementation of a single stage Sediment Retention Structure (SRS).

The Mount St. Helens Decision Document, which presents the results of the CP&E studies, represents the best professional analysis possible, given the inherent uncertainty arising from the sediment budget estimate and altered hydrology of the affected watershed. The Decision Document sets a new standard for

Corps of Engineers planning reports and will serve as a model for future efforts. State, local, and Federal decision makers will find useful the explicit treatment of uncertainty and aid them in their appreciation of the trade-off between risk reduction and cost.

During the CP&E studies new information was developed on:

> The nature and magnitude of sediment deposition and the uncertainty inherent in the sediment budget estimate.

> The magnitude and location of flood damages and flood risks that exist in the Toutle and Cowlitz watersheds.

Additional information includes the following:

> That the significant flood risk is confined principally to a few specific locations within the existing leveed Cowlitz River flood plain.

> That no threat exists to Columbia River navigation, except from events whose probability of occurrence, in any given year, is very small.

> That sediment budget predictions are essential to defining the National Economic Development (NED) Plan.

> That 550 MCY, in the judgment of the Chief of Engineers, is the appropriate estimate of the sediment budget for the next 50 years.

> That the uncertainty that clearly is present is different than that encountered in other Civil Works projects. The Corps has less experience and less data on which to base decisions than typically is the case. And while Corps estimates of the total sediment budget have decreased from 1 BCY in 1982 to the present 550 MCY estimate, the amount of sand that must be managed has in fact gone up -- notwithstanding that actual measured sediment delivery, either

to the Toutle or Cowlitz River, as seen in Table II-1 on page II-2, has declined since 1982.

> That the sources of sediment are (1) erosion of materials deposited by volcanic activity since 1980, and (2) sediment material to be made available for erosion as a result of volcanic activity yet to occur.

> That 115 MCY, that is, 21 percent of the 550 MCY estimated sediment budget, is derived from Corps models of sediment erosion and transport of materials deposited since 1980.

> That not less than 65 percent, and perhaps as much as 79 percent, of the estimated sediment budget is derived from adjustments made for analytical uncertainty and unpredictable future volcanic activity.

> That if the sediment budget proves to be less than 65 percent of the 550 MCY estimated sediment budget, the NED Plan is dredging.

This information and the analysis of alternatives suggest, as the Chief of Engineers points out, that either an SRS as recommended in May or dredging could be deemed acceptable in terms of affording a reasonable solution to the flood problem. In fact, these alternatives, as shown in Table VI-1 on page VI-4, have been designed to provide identical outputs; that is, the levels of flood protection available at the beginning of each water year are identical. However, with the dredging alternative, temporarily reduced levels of flood protection might be realized if during a water year an extremely low probability storm or mudflow event occurs. Should such an event occur, levels of protection would be restored by accelerated dredging.

I recognize that decision makers -- possessed of objectives, concerns, and premises different from my own -- may reach a different conclusion as to whether the SRS or dredging is the better plan. In this

connection, Table VI-4 on pages VI-9 and VI-10 of the Decision Document summarizes, in systematic fashion, the implications of differing beliefs about the sediment budget and other factors that affect the decision on the best permanent solution to the flood problem.

The April 3, 1985, report of the Chief of Engineers and accompanying supplement on Mount St. Helens Sediment Control contained a criterion for deciding under what conditions the Secretary of the Army could select an alternative to the single stage Sediment Retention Structure:

> . . . The Secretary of the Army may select and implement a staged sediment retention structure at the confluence of the Toutle and Green Rivers, or dredging alternative on the Toutle, Cowlitz, and Columbia Rivers if he determines that continuing monitoring of sedimentation and further analysis of benefits and costs provide compelling and convincing new evidence to justify selection of a staged retention structure or dredging alternative.

While the analysis contained in the Decision Document raises uncertainties about what ultimately may be the better solution, it is clear, in my judgment, that the Decision Document does not provide compelling and convincing new evidence to choose other than the SRS at this time. Further, Congress already has made known its preference for an SRS by authorizing its construction in Public Law 99-88, the Supplemental Appropriations Act, 1985. Therefore, I concur in the recommendation of the Chief of Engineers that the single stage Sediment Retention Structure be implemented.

The recommendation for implementation of the SRS, together with the analysis set forth in the Mount St. Helens Decision Document, clarifies the basis for final engineering and design and for budgetary decisions. As is true with other potential new construction starts nationwide, local cooperation agreements and consideration of Federal budgetary priorities will

be essential to scheduling of implementation of the long-term solution. The Corps currently estimates that, during the first four years of construction of the SRS, the total cost of the retention structure will be $78 million, down considerably from the $136 million estimate contained in the Feasibility Report.

Sincerely,

Robert K. Dawson
Acting Assistant Secretary of the Army
(Civil Works)

Enclosure

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

DAEN-ZA

11 OCT 1985

MEMORANDUM FOR THE ASSISTANT SECRETARY OF THE ARMY (CIVIL WORKS)

SUBJECT: Mount St. Helens Sediment Control Decision Document - ACTION MEMORANDUM

Attached is the Mount St. Helens Sediment Control Decision Document and the findings, conclusions, and recommendations of the District and Division Engineers.

Since the eruption of Mount St. Helens in 1980, the Corps of Engineers has been very active in recovery operations and the planning and implementation of permanent solutions to the problems caused by the eruption. The Portland District has been the office that has had the responsibility to plan, design and implement these solutions. It has not had to work alone, however, as the North Pacific Division office, the Office of the Chief of Engineers, and your staff have been actively involved. The resulting document is the result of the best professional analysis and judgment at all levels throughout the Corps.

We recognize that the establishment of the sediment budget is one of the key factors in making a decision on the best permanent solution to the flooding problems associated with the sediment resulting from the eruption of Mount St. Helens. The Sediment Control Decision Document presents a sediment budget with a total volume of 550 million cubic yards (MCY) as the most likely budget. The document recognizes that, because of the budget's dependence upon the forecast of natural phenomena, the budget has inherent uncertainties. Among these are the problems associated with dealing with an active volcano. Our experience with the erratic behavior and the associated sedimentation problems of an active volcano is limited although we have augmented our knowledge by calling upon experts from the U.S. Geologic Survey, academia, and Japan. I have carefully considered the factors that influence the budget and have discussed it at length with my technical staff and agree with the experts both within and outside of the Corps who feel that the 550 MCY budget is the appropriate estimate upon which to base a decision. Yet, I acknowledge that there is clearly uncertainty present.

Recognizing that the sediment budget is the key element in the selection of an appropriate solution, we must not be lulled into complacency by the fallacy of a smooth average curve. The sediment budget is depicted by a smooth, exponentially decreasing curve and all the economic analyses are based upon that curve. In reality, the actual sediment curve will consist of peaks and valleys, which over time are expected to yield 550 MCY. The solution must be capable of safely and efficiently dealing with the peaks to avoid serious flooding.

I have reviewed the alternatives presented; dredging, and single and staged sediment retention structures (SRS), and believe that they have been evaluated fairly and equally. In considering these plans, I believe that the following factors are the most important in reaching a decision on the best plan to implement.

1. In comparison to the Feasibility Report, we now have more and better data to describe the magnitude of the problem, flooding in the Toutle and Cowlitz valleys, and more detailed analyses of the alternatives' ability to solve it.

2. All of the alternatives provide a reasonable reduction in flood damages; however, the SRS plans can better accommodate the uncertainties in the sediment budget and respond to the peaks in sediment delivery. In this regard, the SRS's are more proactive rather than reactive to changes in the sediment budget and have greater flexibility to handle future events. Dredging's mobilization requirements and capacity to move a large amount of sediment in a short period of time preclude this alternative from being responsive to successive events.

3. The social, economic, and environmental impacts in the Toutle and Cowlitz valleys and in the State of Washington are less for the SRS's than for dredging. The disposal problems associated with the 550 MCY budget are significant. We estimate that the dredging alternative would require approximately 124 MCY more disposal than the SRS alternative.

4. The sensitivity analysis shows the SRS's to be able to deal with a wider range of sediment budgets than can the dredging alternative. Even if the budget drops below the transition point you have not lost a great deal because the outyear dredging component of the SRS plan can be reduced, postponed, or deleted. In the meantime, the SRS continues

to provide the advantages I have pointed out above. In terms of cumulative budgetary outlays, the SRS is more costly for the first five years, but dredging then becomes more expensive for the remainder of the project life.

5. Additionally, I note that the SRS is currently supported by the state and local governments and Federal agencies while dredging is not.

The Comprehensive Plan and the Feasibility Report both concluded that an SRS was the best alternative to provide a permanent solution to the flooding problems resulting from the sedimentation from Mount St. Helens. The analyses recently completed under CP&E and documented in the Decision Document also reached the same conclusion. My staff and I have given careful consideration to the information provided in the document and to the discussions conducted with your staff. Therefore, I concur with the recommendations of the District and Division Engineers in recommending the NED plan consisting of a levee fix at Kelso, a single stage SRS at the Green River site with a spillway elevation of 125 feet, and initial and outyear dredging in the Toutle and Cowlitz Rivers. I also recommend that you concur in the selection of the NED plan and that the Corps proceed with its implementation.

The recommendations contained herein reflect information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and/or implementation.

E. R. HEIBERG III
Lieutenant General, USA
Chief of Engineers

Enclosure

NPDPL-PF (Oct 85) 1st End
SUBJECT: Mount St. Helens, Washington Decision Document

DA, North Pacific Division, Corps of Engineers
P. O. Box 2870, Portland, OR 97208-2870 8 October 1985

TO: CDR, USACE (DAEN-CWZ-A), 20 MASS AVE NW, WASH DC 20314-1000

1. I have reviewed the Portland District Commander's report evaluating alternative solutions for reducing the flood threat to communities along the Cowlitz River. I find the report presents a professional and comprehensive analysis of the complex problems associated with predicting sediment movement and flooding potential in a river basin devastated by an active volcano. Portland District incorporated the advice and guidance of recognized experts both inside and outside the Government. It is my opinion that the predicted sediment yields displayed in Chapter 2 and Appendix A represent the most reliable sediment forecast and problem statement that the engineering community can develop at this time.

2. In evaluating the Portland District report I first considered both the uncertainty of predicting sediment movement and the consequences of either underestimating or overstating the problem. During this evaluation I found that a part of the sediment budget is based on significant sediment yields from volcanic induced mudflows. It is my opinion that lesser but still significant sediment yields from the area above Coldwater and Castle Creeks would result from normal hydrologic processes regardless of volcanic activity. Thus, I find the flood threat to the communities of Longview, Kelso, Lexington, and Castle Rock, Washington to be real even during periods of reduced volcanic activity. Further, I recognize that solutions were formulated on average annual hydrologic and volcanic yields. In reality, yields during individual years will vary greatly above or below the average annual yield. Thus, although the alternative solutions appear to provide equal protection from the effects of sediment transport, they in fact, offer differing reactions to major hydrologic or volcanically induced events. It is my view that, because of the potential for extreme hydrologic events, multiple storm sequences, and/or volcanic actions, the plan including a sediment retention structure affords the highest degree of protection against flooding. Secondly, I considered the economic analysis, the views of local interests, and environmental impacts of the alternatives. In view of the above, I conclude that the plan identified as the NED plan provides the best solution to this complex problem.

3. The potential for disrupting commercial navigation on the Columbia River is another matter for concern. The District analysis predicts no navigation disruption from Mount St. Helens sediments unless major storms occur. Although this analysis is appropriate for the Decision Document, I believe navigation disruption could occur if major amounts of sediment are

transported to the Columbia River when its flushing actions are reduced during a low flow period. Such disruption would be of short duration since adequate authority and procedures are in place to alleviate any disruptions.

4. In conclusion, I have carefully reviewed the data, analysis, and conclusions presented in this report. I concur in the Portland District Commander's recommendation to proceed with implementation of a sediment retention structure, with a 125 foot spillway height, on the North Fork Toutle River, with associated downstream dredging,and improvements to the levee at Kelso, Washington.

George R. Robertson

GEORGE R. ROBERTSON
Brigadier General, USA
Commanding

SYLLABUS

This report analyzes management strategies for dealing with Mount St. Helens-related sedimentation and resultant flooding in the Toutle/Cowlitz/Columbia river system. Measures considered include a single sediment retention structure constructed in one stage (SRS) or multiple stages (MSRS), dredging, and levee raises at lower Cowlitz River Valley communities.

The recommended plan is a combination of a SRS (125-foot spillway) at the Green River site on the North Fork Toutle River, minimal levee improvements at Kelso, Washington, and dredging downstream from the SRS during its construction and in later years of the project when the reservoir has filled and sediment begins to pass over the spillway.

This is the National Economic Development (NED) plan, representing the program which will produce the greatest net economic benefits among those considered. In general, its social and physical environmental effects are considerably lower than any management strategy which depends principally on dredging. While requiring mitigation for fish runs into the upper North Fork Toutle River, this plan improves water quality and reduces environmental impacts everywhere downstream from its location. Because much of the sediment will be retained behind the structure, this program will avoid substantial downstream disposal site mitigation.

Of those sites feasible, the Green River site provides the best geologic and farthest upstream location for the earth embankment structure and sediment impoundment area. The structure alone will provide sufficient sediment storage to achieve 167-, 11-, 167-, and 118-year permanent safe flood protection (PSP) at Longview, Kelso, Lexington, and Castle Rock, respectively, over the 50-year project life. The PSP becomes 167-, 143-, 167-, and 118-years at the four communities with levee improvements. The SRS also provides storage for the sediment from a 100-year frequency storm. If monitoring programs suggest more capacity is needed in the reservoir for either rare events (floods or mudflows) or unexpectedly high erosion from the avalanche, it is possible, at additional cost, to raise the spillway and/or crest of the structure when needed.

This program will cost $231.1 million in 1985 dollars. Construction of the SRS, fish bypass, and levees accounts for $65.7 million of those costs. Initial dredging accounts for another $25.4 million and real estate and relocations are $18 million. Other costs, including O&M, monitoring, and outyear dredging total $122 million.

The SRS/levee improvement/dredging strategy recommended is the best alternative when economic, environmental, and engineering considerations are weighed. Preliminary analyses indicate that future raises of the SRS spillway are slightly more economical than outyear dredging along the Cowlitz River. This recommended plan provides more flexibility and safety in managing the unique sedimentation and flooding problem presented by the Mount St. Helens eruption than a dredging only or dredging and minimal levee raise strategy.

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CHAPTER I - INTRODUCTION

BACKGROUND

History of Flooding

The 18 May 1980 eruption of Mount St. Helens deposited a debris avalanche of over 3.8 billion cubic yards (bcy) of silt, sand, gravels, and trees in the upper 17 miles of the North Fork Toutle River Valley. Another 50-60 million cubic yards (mcy) of material were deposited in the upper portion of the South Fork Toutle River Valley. The eruption devastated approximately 150 square miles of prime evergreen forests, mountain lakes, and the wildlife in that area. Mudflows, triggered by the eruption, carried large volumes of sediment from the debris avalanche into the Toutle/Cowlitz/Columbia river system. Widespread flooding along the Toutle and Cowlitz Rivers and blockage of the Columbia River navigation channel resulted. The hydrologic cycle of rainfall, runoff, infiltration, transpiration, evaporation, sublimation, and condensation was drastically altered.

Since 1980, large quantities of sediment have eroded from the avalanche and been transported by the river system. A substantial portion of that material has been deposited in the Cowlitz River, reducing its channel capacity and increasing potential flood heights. The large volume of sediment transported to the Columbia River after the initial eruption interrupted navigation on that waterway. The Corps of Engineers, Portland District, responded to the threat of flooding along the Cowlitz River and interruption of navigation on the Columbia River by implementing emergency measures along the three rivers impacted by the eruption and by studying future actions. These measures were designed to reduce the threat of flooding by retaining the sediment in the Toutle River basin, enlarging the clogged Cowlitz River channel, raising existing and constructing permanent new levees in urbanized areas along the Cowlitz River, and eliminating the threat to navigation by dredging in the Columbia River to restore the 40-foot deep by 600-foot wide navigation channel. Since 1980, the Corps of Engineers has spent over $375 million for emergency actions (see Table I-1) and will continue responding to any emergency threatening life and property.

TABLE I-1
MOUNT ST. HELENS EXPENDITURE SUMMARY
($000)

Appropriation/ Activity	Fiscal Year 1980	1981	1982	1983	1984	1985	TOTAL
Flood Control							
Coastal Emerg.							
Dredging	39,056	102,826	1,564	3,338	11	34	146,829
Structures	9,276	65,315	6,303	2,870	83	1,228	85,075
Spirit Lake	0	0	1,283	6,609	7,891	10,957	26,740
Monitoring	0	0	1,700	937	58	2	2,697
E&D, S&I	2,368	7,145	1,433	1,733	1,498	1,193	15,370
TOTAL	50,700	175,286	12,283	15,487	9,541	13,414	276,711
Operations & Maintenance							
TOTAL	20,300	21,900	7,900	7,700	7,187	7,325	72,312
General Investigations							
Sediment Control Permanent Solution							
TOTAL	0	0	37	2,616	1,780	5,855	10,288
Construction General							
100 Year Temporary							
Flood Protection (PL 98-63)	0	0	0	6,302	18,253	6,600	31,155
Spirit Lake	0	0	0	1,255	14	0	1,269
Sed. Control Perm. Sol.	0	0	0	0	0	0	0
TOTAL	0	0	0	7,557	18,267	6,600	32,424
GRAND TOTAL	$71,000	$197,186	$20,220	$33,360	$36,775	$33,194	$391,735

AUTHORITY AND PURPOSE

On 18 May 1982, President Reagan (through a Memorandum to the Secretary of Defense) requested that the Corps of Engineers prepare a report addressing alternative strategies for handling the projected movement of sediment. The strategies were to minimize the continuing problems of flood hazards and potential disruptions to navigation based upon engineering feasibility, economic merit and environmental sensitivity.

The report, "A Comprehensive Plan for Responding to the Long-term Threat Created by the Eruption of Mount St. Helens, Washington," was forwarded to the President in November 1983. The plan evaluated five alternative strategies for sediment control and analyzed six alternative outlets for stabilizing the level of Spirit Lake. In transmitting the Comprehensive Plan report, the Assistant Secretary of the Army for Civil Works (ASA[CW]) recommended finding a permanent solution to the sediment problem that could be forwarded for Congressional authorization and funding. In response to ASA(CW) direction, a Feasibility Report containing an Environmental Impact Statement was prepared and transmitted for further action in December 1984. The final Chief of Engineer's report, dated April 3, 1985, was reviewed by ASA(CW) and forwarded to the Office of Management and Budget on May 10, 1985, for review. Key elements of that report are: Analysis of the Sedimentation Problem, Evaluation of Structural Alternatives, Identification of the National Economic Development (NED) Plan, and a Cost-Sharing Formula. A summary of that information appears later in this document. Since preparation of the Feasibility Report, studies have been initiated under Continued Planning and Engineering (CP&E) authority as requested by ASA(CW).

The purpose of this document is to recommend a program of action by analysis and optimization of four sets of measures: a Single Retention Structure (SRS), a Staged Single Retention Structure (MSRS), dredging, and levee raises. With the exception of levee raise options, these measures will be evaluated alone and in appropriate combinations to identify the most effective program. In the dynamic Toutle/Cowlitz river system, unmanaged sedimentation can constantly raise water surface levels; consequently, protection from a given levee measure without sediment control would continually diminish.

Levees are most effective when combined with a retention structure or dredging program to maintain channel geometry. Therefore, levees were not considered singly.

STUDY AREA

The study area encompasses 1,200 square miles (sq. mi.) in southwest Washington, reaching north from the Columbia River to the headwaters of the Toutle River at Mount St. Helens. A vicinity map and a more detailed map of the study area are shown in Figures I-1 and I-2, respectively.

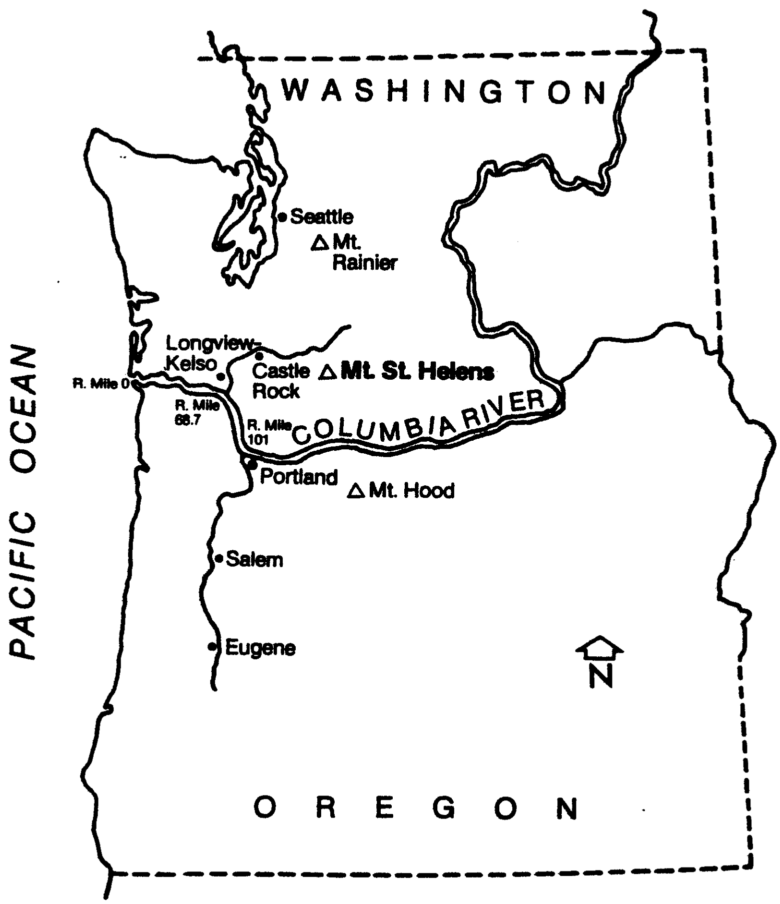


FIGURE I-1. VICINITY MAP

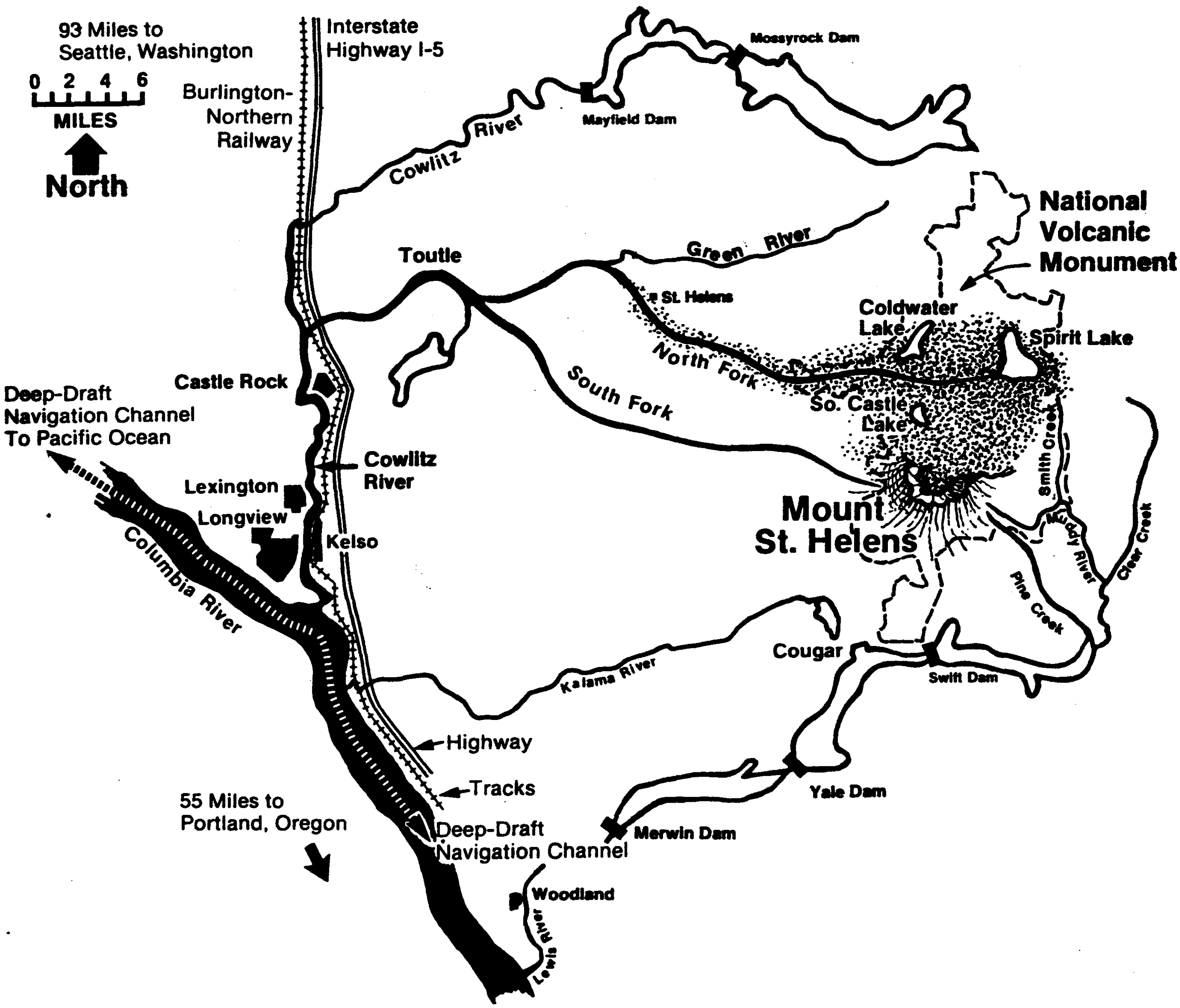


FIGURE I-2. STUDY AREA FOR THE DECISION DOCUMENT

The Columbia River flows east to west through a broad trough between the Cascade and Coast mountain ranges. It provides the navigation channel for vessels enroute from the Pacific Ocean to the deep-draft Ports of Vancouver, Washington, and Portland, Oregon. The reach of primary interest lies between river miles (RM) 60 and 72. Lands along both shores, Oregon on the south, Washington on the north, consist of a narrow valley bottom adjacent to low hills. Several small, low-lying islands are located in this reach of the river.

The Cowlitz River and its principal tributary, the Toutle, are typical of rivers draining the west slopes of the Cascade Range. The terrain is mountainous and, except for clearcuts and areas devastated by the 1980 eruption, heavily forested.

The Cowlitz River drains an area of 2,480 sq. mi., including the Toutle River drainage area. Below its confluence with the Toutle, the lower 20 miles of the Cowlitz passes by the towns of Castle Rock, Lexington, Kelso, and Longview, Washington, before entering the Columbia River at RM 67.8.

The major tributaries of the Toutle River drain 432 sq. mi. The South Fork Toutle drains 129 sq. mi. and the North Fork Toutle, 303 sq. mi., including 131 sq. mi. from the Green River. In addition, the lower Toutle drains 80 sq. mi. for a total drainage area of 512 sq. mi. The North and South Fork Toutle Rivers have their headwaters on the slopes of Mount St. Helens and carry runoff and sediment westward to the Cowlitz River. The North Fork Toutle River Basin includes three major lakes, South Castle, Coldwater, and Spirit.

The area affected by potential flooding varies from bottom land along the Cowlitz to uplands at the base of the mountains of the Cascade Range. Industrial riverfront and urbanized property lie adjacent to both the Columbia River and the downstream reaches of the Cowlitz River. Further up the Cowlitz, adjacent property is less populated, changing from urban to agricultural land use. The upper portion of the Toutle River Basin, except the volcanic and mudflow areas, is managed forestland.

PAST PLANNING ACTIVITIES

The Comprehensive Plan (1983) contained the first in-depth analysis by the Corps of Engineers of the flooding and sedimentation problems resulting from the eruption of Mount St. Helens. A sediment budget and a deposition analysis were developed as a base for quantifying the size and duration of potential flooding and navigation blockage. A total of 1 billion cubic yards (bcy) was estimated to erode in the 50-year study period. From an initial 13 potential measures, some of which were expansions of those used during emergency operations, five alternatives were proposed to permanently solve the sedimentation problem. They were:

1. Limited permanent evacuation
2. Sediment stabilization basins
3. Multiple retention structures with dredging
4. Multiple retention structures without dredging
5. Single retention structure

In addition, six alternatives were suggested to prevent a potential breach of Spirit Lake:

1. Permanent pumping
2. Open channel
3. Buried conduit
4. Tunnel (east) to Smith Creek
5. Tunnel (west) to N. Fork Toutle
6. Tunnel (west) to S. Coldwater Creek

Because a breach of Spirit Lake might have occurred with no action and in a very short timeframe, implementing a solution to that problem was accelerated. The South Coldwater Creek Tunnel alternative was selected, and construction was completed in April 1985. The lake is now stabilized at elevation 3440 feet National Geodetic Vertical Datum (NGVD). This work has produced the additional benefit of bypassing the water discharge from Spirit Lake around a portion of the highly erodible debris avalanche.

An optimization analysis based on least-cost for equal outputs was performed on the five alternatives identified in the Comprehensive Plan for solving the sediment problem. A Single Retention Structure (SRS) on the North Fork Toutle upstream from the Green River was the most cost-efficient on the basis of the then predicted erosion rates and timing and was selected as the NED Plan. A subsequent sensitivity analysis confirmed that the SRS remained the most cost-effective option, if the sediment budget was greater than approximately 54 percent of the predicted amount. This finding, as part of the Comprehensive Plan, was transmitted to the President in October 1983.

In a 3 November 1983 Memorandum to the Secretary of the Army, the Assistant Secretary of the Army for Civil Works (ASA[CW]) requested that further analysis concentrate on one or more SRS structures at the lowest feasible site in the basin. He further directed that other stages or structures should be planned for construction if and when needed. The rationale for proceeding with the feasibility stage of planning was founded in the unique nature of the problem created by the eruption. Consequently, the uncertainty of predicting erosion rates with field data from a very short post-eruption period necessitated a series of assumptions to predict the sediment budget. It was stated by the Assistant Secretary that notwithstanding the Corps' best estimates of erosion rates, actual stabilization of the Toutle basin by natural processes might occur more rapidly than anticipated. Thus, any programmed solution should provide flexibility to adjust to actual conditions.

Although the SRS was cost-effective over a wide range of the sediment budget, this did not constitute flexibility, as it requires a large initial cost. If the movement of sediment was less or slower than predicted, a smaller second stage would allow for significant saving of funds required from the Federal, state and local treasuries.

A feasibility study was initiated to recommend a permanent solution to the sedimentation and flooding problems for congressional authorization. The sediment budget was revised to indicate erosion of 650 mcy of material from the debris avalanche during the 50-year economic project life. A sensitivity analysis again concluded that the SRS was the best plan for handling erosion from the debris avalanche above 65 percent of the estimated sediment budget.

The Acting Assistant Secretary of the Army, after reviewing the Feasibility Report (1984), concluded that the concerns expressed in the 3 November 1983 memorandum were still valid. As a result, three options, SRS, staged SRS, and dredging, were to be evaluated during Continuing Planning and Engineering.

The sedimentation problem is recognized as both dynamic and unique for a variety of reasons. No historical data existed because the volcanic eruption altered the river systems in the basin. Selection of modeling procedures involved both executing various models, as data became available, and evaluating their performance. As knowledge expanded, the most recent sediment budget replaced the previous one. The forecasts used in the Feasibility Report superceded those in the Comprehensive Plan and, in turn, the new budget and analysis presented in this report will replace that from the Feasibility Report. Increased field data, modeling capability, and verification of model results with observed flood data have improved estimates. However, the lack of historical data for such a major change in basin characteristics poses a degree of uncertainty in analytically identifying a preferred plan.

STUDY SCOPE

At the direction of ASA(CW), the CP&E studies underway include analyses of three measures: dredging, a SRS, and a MSRS, all to an equal level of detail. Levees are also considered as additions to each of the above measures.

This study addresses the permanent solution to potential flooding on the Cowlitz River and possible disruption of navigation on the Columbia River caused by sediment buildup. It, therefore, focuses on the remaining problem of sediment buildup. This study includes: 1) updating the sediment budget; 2) redefining the problem consistent with that update; 3) describing and analyzing measures to deal with the redefined problem; 4) comparing the environmental effects of the measures; 5) determining a National Economic Development (NED) plan; and 6) recommending a solution to the problem.

CHAPTER II - SEDIMENT BUDGET AND PROBLEM STATEMENT

GENERAL CONSIDERATIONS

The purpose of this chapter is to provide an update of the sediment budget and revise the problem statement to reflect the updated budget. As this is done, comparisons to previous sediment forecasts and associated problem statements will be offered. A "base" condition of flood protection for lower Cowlitz River communities is authorized in PL 98-63. That base is the "without project" condition. A "no-action" scenario is presented as an analytical baseline only. The no-action alternative is a basic let-nature-take-its-course approach and will result in no expenditure of funds to reduce flood threat or damage. The flood damages under a "no-action" and a "base" response are described as part of this problem statement.

THE SEDIMENT BUDGET

Recent Rainfall Events, Flow Rates, and Measured Deposition

Basic data for sediment forecasting includes measurements of streamflow, erosion, sediment transport, and deposition. Records in the Toutle/Cowlitz/Columbia system relevant to this analysis start in water year (WY) 1981 and continue to the present. In that time period, annual precipitation in the area has approached the average during years 1981 and 1984, was below normal in 1985, and was above normal in 1982 and 1983. The 3 December 1982 storm, which produced an estimated 15-20 year North Fork Toutle River discharge of 16,300 cfs, remains the highest peak discharge observed. A series of storms in February 1982 had the largest sediment production. Table II-1 depicts streamflow and sediment movement in the system from WY 1981 through WY 1985. Though annual streamflows have remained near constant since 1982, the intensity of winter storms has decreased yearly, resulting in lower sediment yields and deposition.

Process for Establishing the Sediment Budget

The sediment budget forecasts total sediment yield and deposition over time in reaches of the Toutle and Cowlitz Rivers, and in the Columbia below its

TABLE II-1
SEDIMENT MOVEMENT AND STREAMFLOW IN THE TOUTLE/COWLITZ/COLUMBIA SYSTEM FOR WY 1981 THROUGH 1985

LOCATION	WATER YEARS				
	1981	1982	1983	1984	1985 1/
Tower Road 2/					
(Toutle RM 6.5)					
Sediment Yield	27 mcy	36 mcy	33 mcy	21 mcy	4 mcy
Streamflow 3/	4/	1.8	1.8	1.7	4/
LT-1 Dredging					
(Toutle RM 1.9-3.3)					
Sediment Removed	4/	0	3 mcy	5 mcy	2 mcy
Cowlitz River					
Deposition	4/	10 mcy	5 mcy	3 mcy	0
Cowlitz River					
Sump Dredging	4/	3 mcy	4 mcy	3 mcy	2 mcy
Cowlitz River					
Yield to Columbia	4/	23 mcy	21 mcy	10 mcy	4/

1/ Partial year, October through February

2/ Measured suspended sediment tonnage converted to cubic yards based on 95 lb/ft^3. Sediment yields include measured suspended sediment plus estimated unmeasured load. This multiple is lower than the 110 lb/ft^3 in-place density prior to erosion because, after transport, the material is redeposited in a loose, poorly-graded condition.

3/ In millions of acre-feet.

4/ In WY 1981 and 1985, there was no gaging station on the Cowlitz River that measured suspended sediment. As a result, it is not possible to make an estimate of sediment transported to the Columbia River.

confluence with the Cowlitz. Preparation of the budget began with characterization of the volcanic deposits, including their composition, volume, slope stability, and distribution. The budget predicted initial erosion rates on the avalanche, composition of eroded materials, limits of stream channel incision and widening, and average annual mudflow contributions. Erosion quantities were estimated using this information. The sediment transportation capabilities and depositional patterns on the Toutle, Cowlitz, and Columbia Rivers were then predicted.

Since estimates were based on the short period of record since 1980 and reflected only moderate to low frequency storm events, the Mount St. Helens Sediment Advisory Group (see Appendix A, Exhibits A-1 and A-2) was formed to review the estimating procedures. The group could concur in the forecast, recommend modifications in the analysis and recalculation, or suggest adjustments to outputs based on their professional judgment. After this expert screening, a recommended forecast was confirmed and used for various planning and operations activities.

The current forecast went through two rounds of analysis and expert review by the sediment advisory group. The first round led to a base estimate of 440 mcy. In reviewing this estimate, the consultants felt that it was low. Their comments were as follows:

"1. We have carefully reviewed the quantities and over-all results of the District's analysis and consider that a degree of conservatism is warranted in the estimate of avalanche yield over 50 years for the following reasons:

a. Even though the monitoring has been at a high quality and quantity level, hydrologic events during the 5 years since the eruption have not yielded a good sampling of what can occur in the future.

b. Modeling studies since our last meeting indicate that much more incision into the avalanche can occur than was previously considered.

c. The possible sequences of channel dregradation, widening and migration within the avalanche area are many and are difficult to predict. Such changes can greatly influence the rate by which erosion decreases with time.

2. As a consequence of this concern, the consultants suggest that the 50-year sediment yield of 440 mcy may be increased by 25 to 50 percent.

3. The primary change is an increase in the erosion downstream of Coldwater Creek because of the increased ability to incise as demonstrated by the model, and availability of material. The suggested yield increase depletes a total of only 15 percent of the avalanche material in 50 years, including 25 percent of the material in the Elk Rock-Coldwater reach."

These comments were considered to be legitimate and the base was increased by 25 percent to 550 mcy.

Thus, the 550 mcy forecast starts from the following premises:

(1) Volcanic and mudflow activity will remain constant at levels observed since the 1980 eruption.

(2) There will be no lake breakouts.

(3) Mudflows will keep stream channels unstable.

(4) Large storms will cause major disruptions of the stream channels, cut them deeply, and erode freshly exposed avalanche deposits.

(5) Channel incision will exceed 12 feet.

(6) Downstream from Coldwater, North Fork Toutle will continue to meander and erode all deposits above the existing stream profile.

(7) Only tributary streams will armor during the project life.

(8) Natural recovery will not significantly affect erosion.

(9) Consultants' recommendations are sound.

(10) The 550 mcy of well-graded material eroded from the debris avalanche would deposit as 640 mcy of poorly-graded material.

Current Deposition and Transportation Conclusions

The current recommended forecast projects 550 mcy of sediment yield from the avalanche between 1986 and 2035. This is a decrease of 17 percent from the Feasibility Report. The initial annual yield is substantially the same as in the Feasibility Report (see Figure II-1), but later exhibits lower volumes at any given point on the curve. The Comprehensive Plan budget is substantially higher and has heavy yield earlier than the current estimate.

However, the 550 mcy budget estimate refers to in-place material prior to erosion. There is a significant increase in volume between a given unit of in-place material prior to erosion and the same unit of material deposited as sediment (see Appendix A). Thus, 550 mcy of erosion bulks to 640 mcy of sediment. The cobbles and coarser gravels in this sediment will stay in the Toutle River. Most of the materials reaching the Cowlitz River will be sands, silts, and clays. Approximately 110 mcy of sand and fine gravels were predicted to deposit in the lower 20 miles of the Cowlitz River over the next 50 years with no action. Most fine sands and all of the clay and silt will enter the Columbia River with its capability to transport substantial volumes of sediment to the ocean. During the project period, more than 500 mcy of sediment is anticipated to leave the system through this sequence without substantial deposition in the Columbia River navigation channel. Table II-2 shows the movement of sediment through the Toutle/Cowlitz/Columbia river system with no action.

The Cowlitz River

Total sand yields to the Cowlitz have increased slightly from the Feasibility Report projection of 370 mcy to 380 mcy over 50 years, so that current annual volumes are now higher than the earlier projected estimates at any given point in time (see Figure II-2). Of greater importance is the pattern of sediment deposited in the Cowlitz over time. Figure II-3 shows that while the Feasibility Report anticipated a peak sediment accumulation of approximately 80 mcy around 2005 and scouring thereafter, the current forecast sees a steady accumulation through 2035 to approximately 120 mcy. As forecasts have changed from the Comprehensive Plan, the amount of expected sedimentation in the

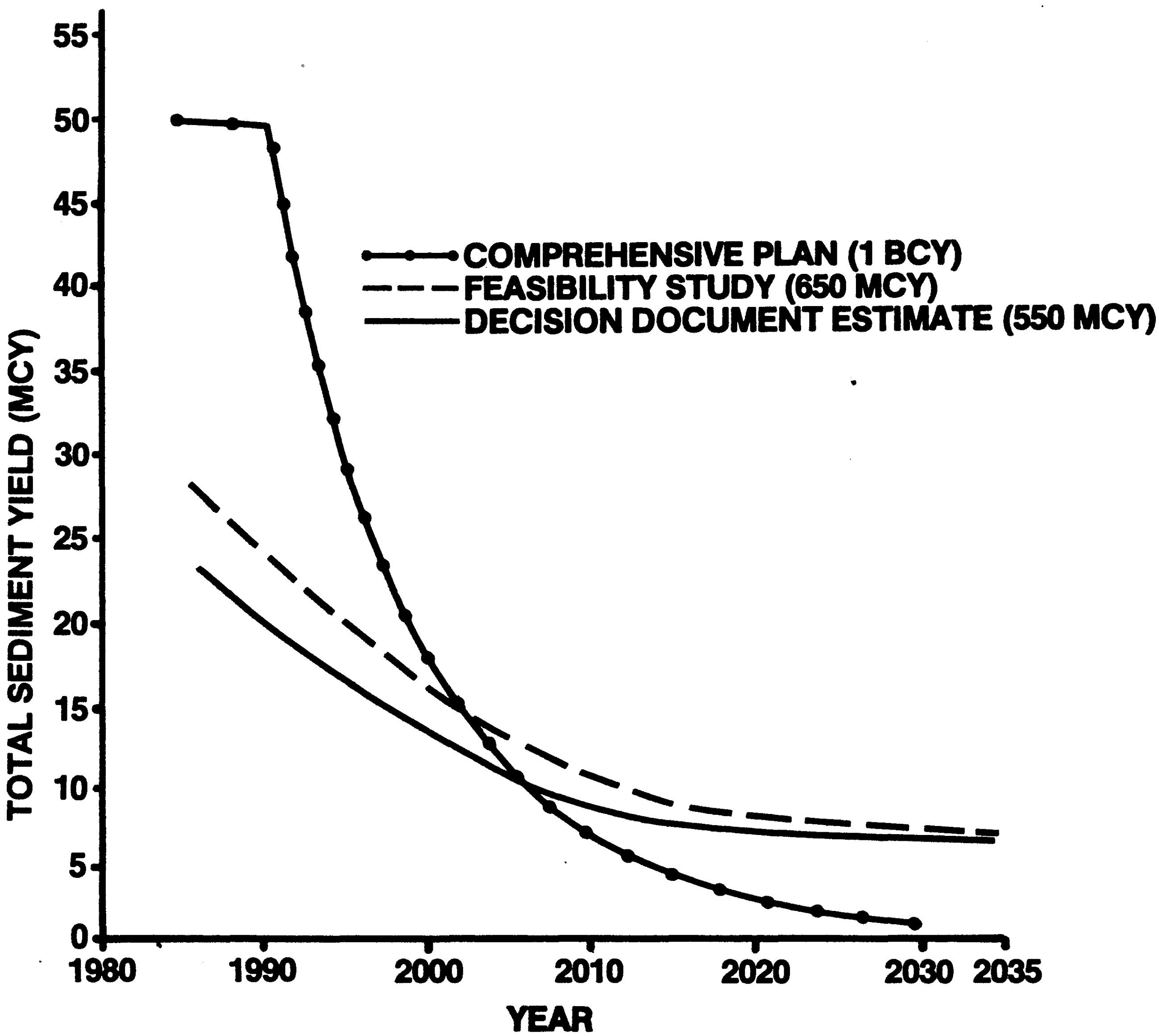


FIGURE II-1: TOTAL EROSION FROM THE AVALANCHE

TABLE II-2
NO-ACTION SEDIMENT MOVEMENT OVER 50 YEARS
(MCY)

Component	Total Sediment	Sand & Gravel	Silt & Clay
Avalanche Erosion	550[1]/	---	---
North Fork Toutle Yield	640[1]/	380	260
Toutle River Yield	640	380	260
Cowlitz River Deposition	110	110	0
Cowlitz River Yield to Columbia R.	530	270	260

1/ 640 mcy refers to the volume of deposition which would result from the erosion of 550 mcy of avalanche material (See Appendix A).

Cowlitz River has increased and a pattern of early deposition and scour has changed to one of continuing deposition. The projected deposition pattern along the Cowlitz River would raise the flood elevations at Castle Rock (RM 17.6) and delay the time at which flood elevations will peak at Longview/Kelso (RM 5.5). Figures II-4 and 5 show the comparative water surface elevations of the 100-year flood for this and the Feasibility Report projections under a no action condition.

The Columbia River

Figure II-6 illustrates that the sediment yield to the Columbia River with no action over the next 50 years is predicted to be somewhat less in this forecast than previous ones, 530 mcy, as compared to 564 mcy in the

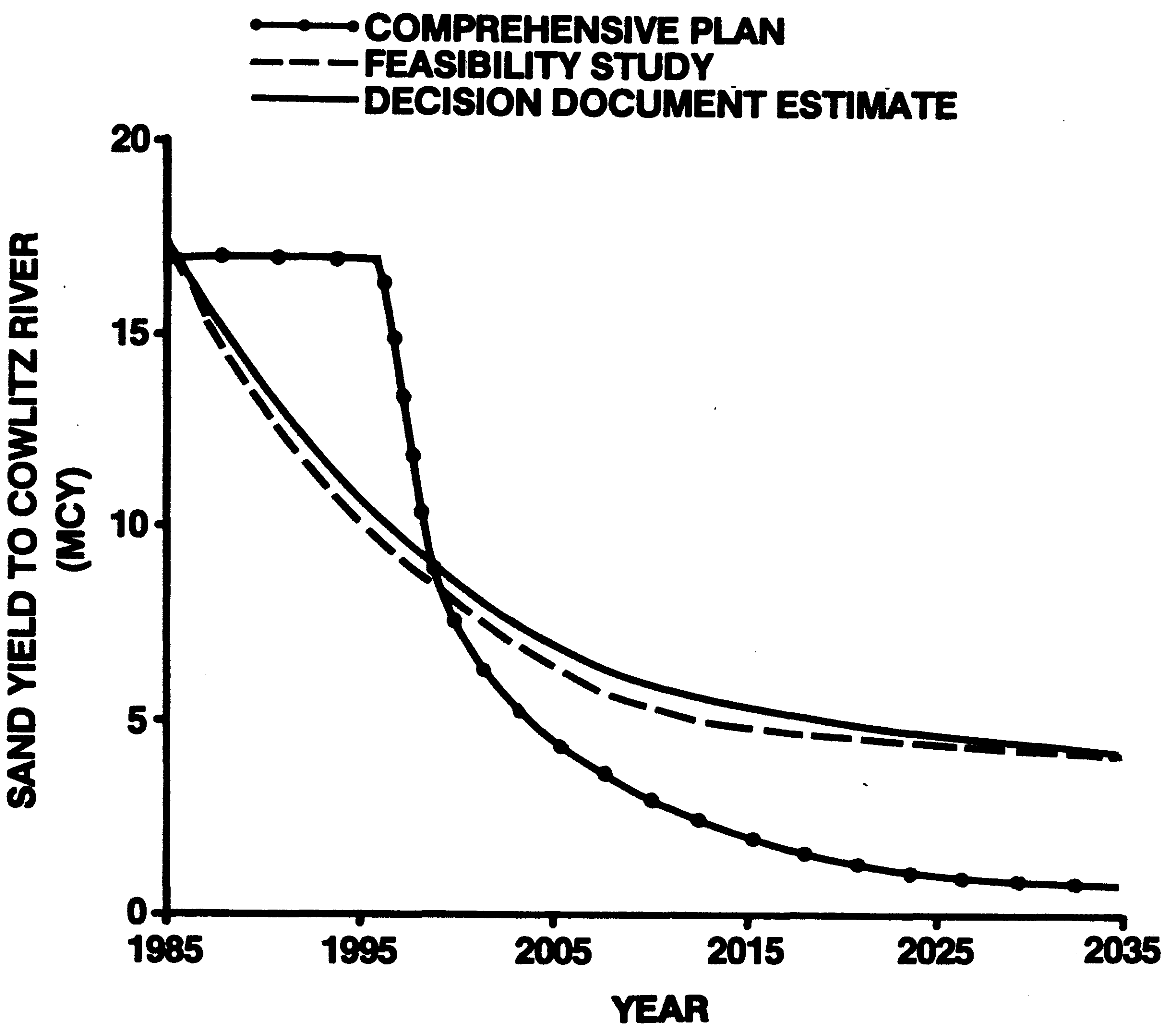


FIGURE II-2: SAND YIELDS TO THE COWLITZ RIVER WITH NO ACTION

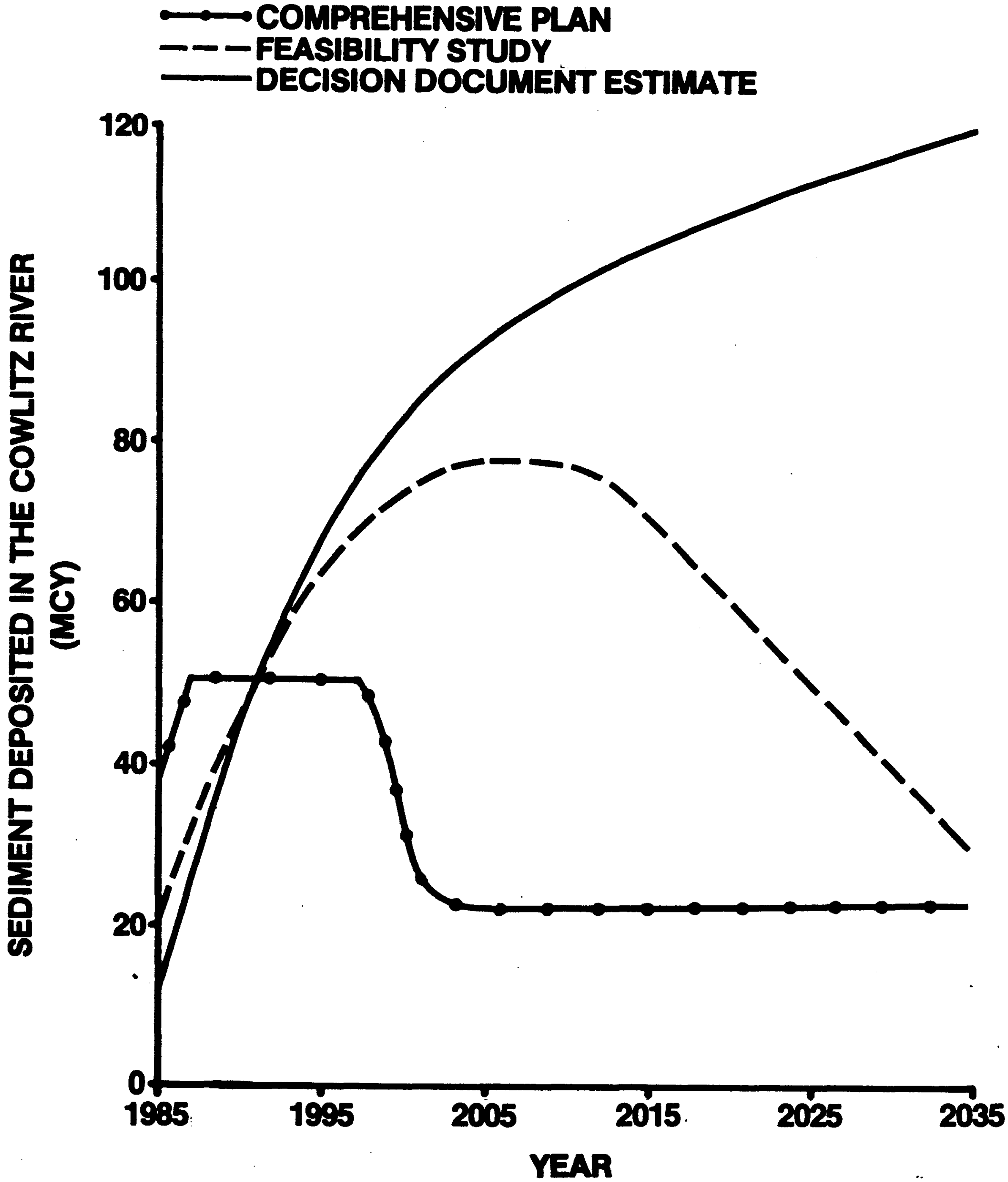


FIGURE II-3: CUMULATIVE SEDIMENT DEPOSITION IN THE COWLITZ RIVER WITH NO ACTION

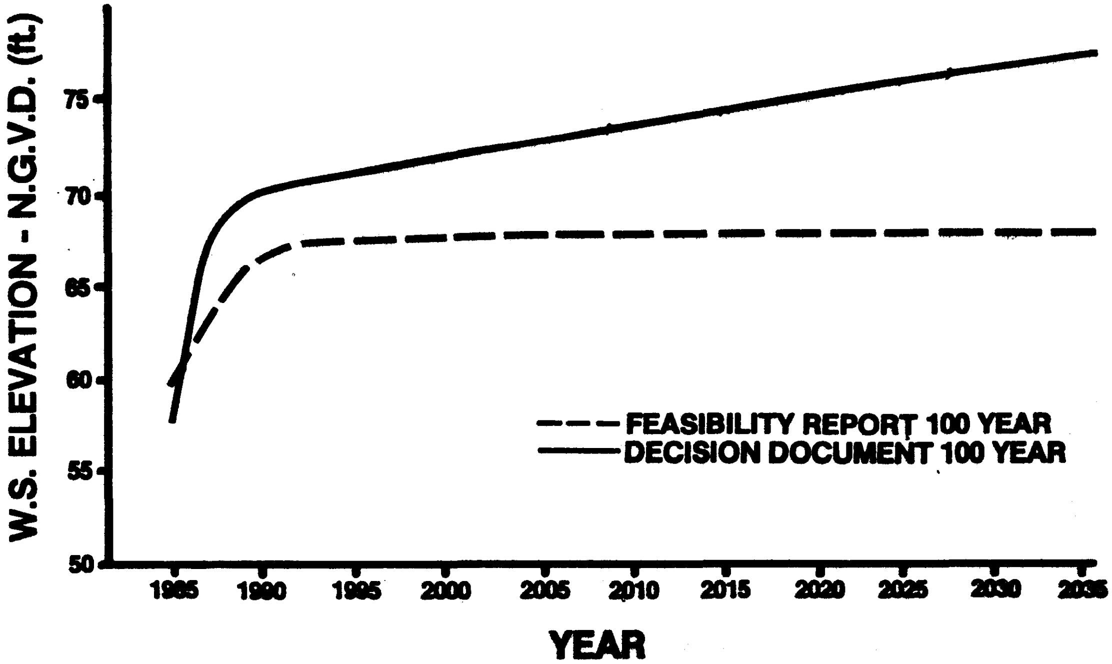


FIGURE II-4: 100-YEAR FLOOD WATER SURFACE ELEVATIONS AT CASTLE ROCK WITH NO ACTION: FEASIBILITY REPORT AND CURRENT SEDIMENT BUDGET

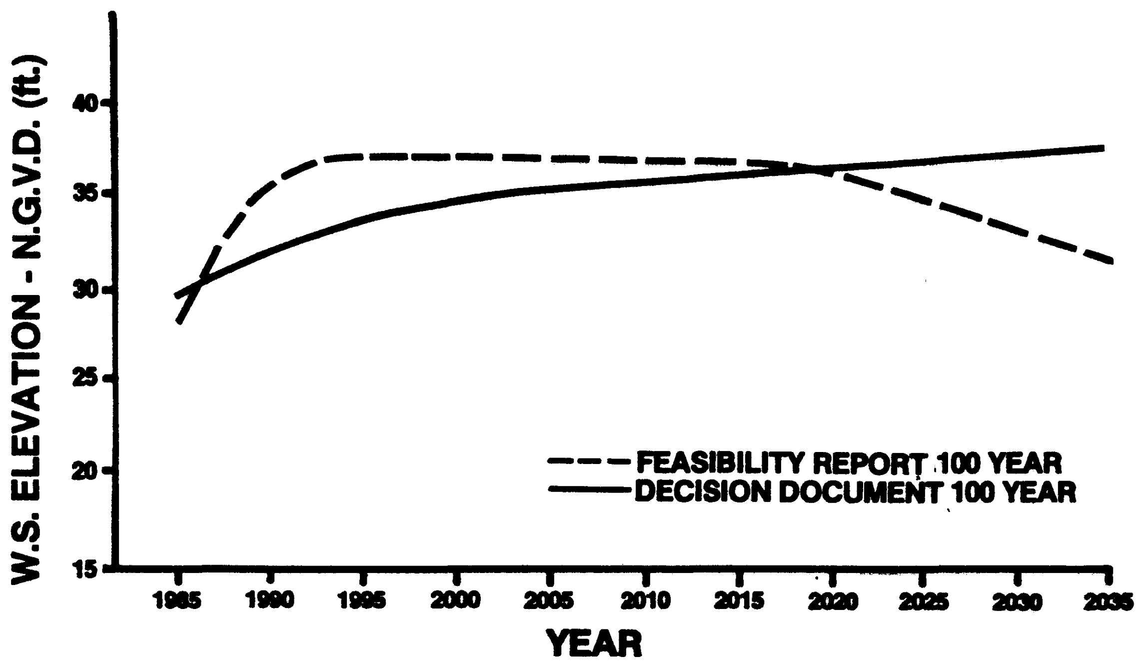


FIGURE II-5: 100-YEAR FLOOD WATER SURFACE ELEVATIONS AT LONGVIEW/KELSO WITH NO ACTION: FEASIBILITY REPORT AND CURRENT SEDIMENT BUDGET

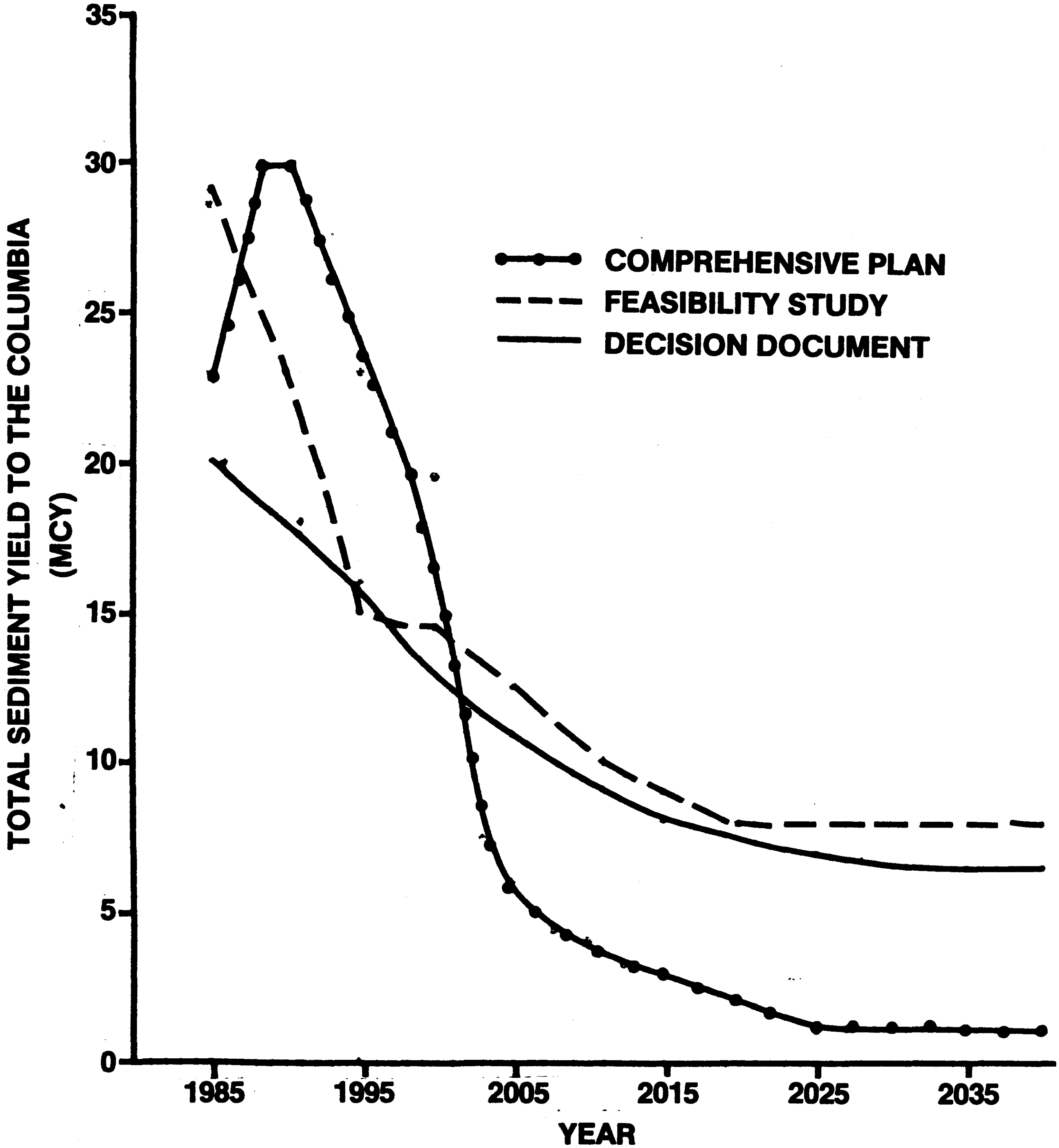


FIGURE II-6: SEDIMENT YIELD TO THE COLUMBIA RIVER
WITH CURRENT AND PAST SEDIMENT FORECASTS

Comprehensive Plan and 629 mcy in the Feasibility Report. Sand yields with no action are less than previous forecasts and follow the same pattern with time as the total yields (see Figure II-7). While a small proportion of the sand was expected to deposit in the navigation channel of the Columbia previously, none is anticipated with the current forecast with average conditions (see Figure II-8). Low probability floods or mudflows, however, may deposit material in the channel.

Basis for the Estimate (E)

The current sediment yield forecast differs from previous ones in three characteristics: (1) lower total erosion over the next 50-years; (2) more continuous and greater deposition of sand-sized material in the Cowlitz River with consequent increases in flood water surface elevations; and (3) expectation of minimal sand deposition in the Columbia River navigation channel attributable to erosion from eruption materials.

Components of the current budget are more refined than in previous forecasts. This is primarily due to more data having been gathered over the past five years with sediment forecasting specifically in mind. Some data in critical categories were simply unavailable for the Comprehensive Plan and scarce for the Feasibility Report. Judgment estimates or volumes from other experience were used in a number of situations. In summary, the present sediment budget is based on more and better data than estimates used in previous reports.

The eruption and mudflow of Mount St. Helens in May 1980 resulted in a major change in the flood peak discharges which occur in the Toutle River Basin. Flood peaks from the Toutle increased up to 40 percent following this event. Two general factors have led to this increase. First, the devastation of the upper watershed which removed all ground cover has led to greater and quicker overland flow runoff during heavy rains. Second is the result of deposition of finer sediments in the North Fork and South Fork Toutle Rivers. This sediment decreased flow resistance, which changed travel times of flood runoff. The more concurrent flood hydrographs among the North Fork, South Fork, and Green Rivers resulted in increased peak flood discharges in the lower Toutle. The debris avalanche is as much as 600 feet thick; the erosion

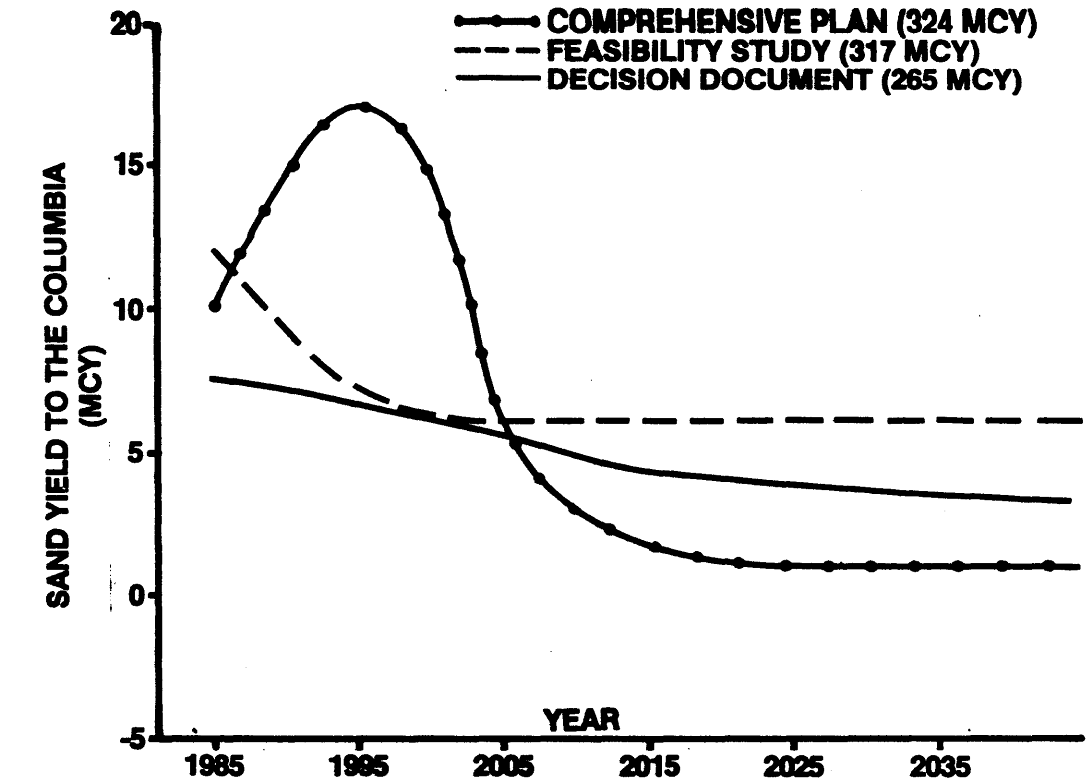


FIGURE II-7: SAND YIELD TO THE COLUMBIA RIVER WITH NO ACTION

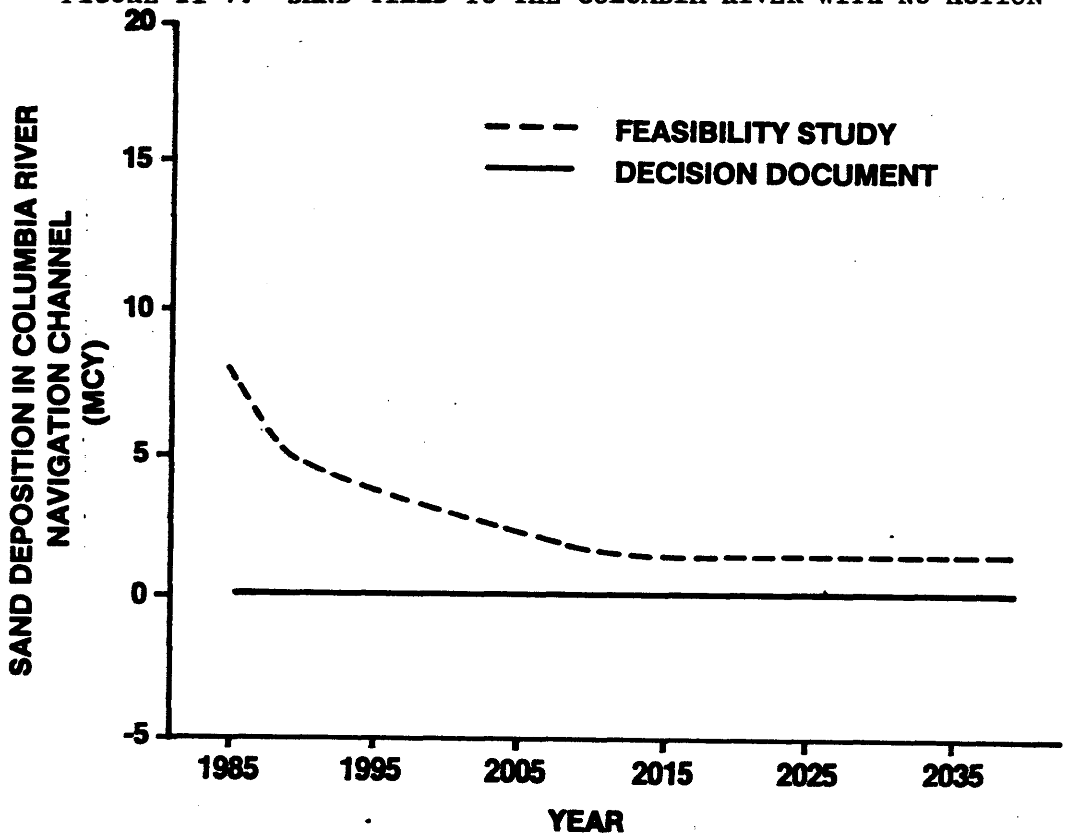


FIGURE II-8: SAND DEPOSITION IN THE COLUMBIA RIVER NAVIGATION CHANNEL WITH NO ACTION

channels meandering across it cut as far as 50 feet deep into the materials. There is little chance of enough stabilization under these conditions for significant revegetation. What plants establish themselves will almost certainly be undermined by normal hydrologic processes. Any revegetation that is occurring is primarily away from the avalanche.

Finally, it must be kept in mind that the sediment estimate reflects long-term average conditions. Part of that average is accounted for by low probability floods and mudflows, events in which substantial volumes of sediment are transported. Thus, in a year with a low probability event, sedimentation can far exceed the average curves represented in the illustrations of the budget outputs. On the other hand, low flow periods will produce less sediment than shown on the average curves.

FLOOD CONDITIONS

During the wet season, November through March, rainfall is typically of light to moderate intensity and continuous over an extended period of time. Flood-producing storms occur generally during these months but are not uncommon in late fall or early spring. High intensity storms are a result of a higher than normal pressure gradient between an Aleutian low pressure area and a Pacific high pressure area. The resulting strong flow of moist marine air into the Pacific Northwest causes heavy precipitation, often in flood-producing quantities. These weather systems often occur as part of a series of fronts which approach the coast with typically 4 to 7 days between fronts. Annual flood-frequency data on the Toutle and possible sedimentation in the Cowlitz are shown in Table II-3.

The U.S. Geological Survey (USGS) recorded 192 flood peaks above the base level of 9000 cfs over the 54-year period of record at 'Toutle River near Silver Lake' gaging station. Multiple 'large' events have also occurred during a single water year. Peaks of 43,200 cfs and 25,300 cfs were recorded during water year 1978 on 2 December and 13 December, respectively. During water year 1982, floods of approximately 35,000 cfs occurred on 24 January and 20 February. Using partial duration frequency computations, a discharge of 35,000 cfs could be expected to be equaled or exceeded an average of 20 to 25

TABLE II-3
SEDIMENT DELIVERY AND DEPOSITION FROM TOUTLE RIVER STORM EVENTS
UNDER NO ACTION CONDITION

Average Exceedence Interval (yr)	Probability	Toutle River at Tower Road Peak Discharges (cfs)	Sediment Delivery to Cowlitz R 2/ (mcy)	Cowlitz R. Deposition (mcy)
2	0.500	25,000	4.8	1.3
10	0.100	41,000	10.8	3.0
50	0.020	56,800	19.0	4.8
100	0.010	64,000	20.6	5.1
500	0.002	81,400	38.5	10.1

times in 100 years. As described, the occurrence of more than one significant flood during a single water year should not be considered as unlikely.

Mudflows

Three mudflows have occurred since the eruption for a total volume of 20 mcy of sediment. With so few occurrences, the probability of a flow with a given volume of material cannot be determined. However, the observed average rate of 5 mcy per year is expected to continue for 50 years. Of that 5 mcy, 2 mcy will be associated with the event and 3 mcy will stay on the avalanche and be discharged later. Figure A-4 in Appendix A shows mudflow volumes from 1980-1985. The chances of a mudflow as great as the one with the 18 May 1980 blast are the same as those of another major explosive eruption. Again, these are unknown.

PROBLEM STATEMENT

Background

The Comprehensive Plan contained a discussion of four potential problem areas resulting from the Mount St. Helens eruption and related ash and avalanche materials: (1) flood damage in the lower Cowlitz Valley related to erosion and deposition of these materials; (2) flood damage associated with lake breakouts, principally from Spirit Lake; (3) disruption of highway and rail traffic where the Interstate 5 transportation corridor crosses the Toutle River; and (4) disruption of navigation in the main channel of the Columbia River. The Spirit Lake outlet tunnel and embankments on the smaller lakes solved the breakout problem. The Feasibility Report dealt with the remaining three concerns.

Current Sediment Budget

This sediment budget differs from previous ones in two ways pertinent to the problem statement. First, total sediment deposition is anticipated to be higher in the Cowlitz River than with any previous forecasts. Second, even with no action, deposition of eruption materials in the Columbia River navigation channel is expected to be minimal under average annual conditions. With low probability hydrologic or mudflow events, significant deposition in the channel could occur. Immediate dredging action, apart from the long-term programs analyzed here, would be undertaken to clear the navigation channel in that eventuality.

Problem Restatement

By this new forecast, the essential problem is reduced to one of flooding in the Toutle/Cowlitz Basin because of increased sediment deposition. Disruption of navigation on the Columbia due to deposition of material from Mount St. Helens is not anticipated during the 50-year period from 1986-2035 under average hydrologic conditions. The approximately 500 mcy of relatively fine materials it receives will enter its flow and move downstream. Two problems remain to be addressed by this document: (1) flooding in the lower Cowlitz,

particularly at Longview, Kelso, Lexington, and Castle Rock and (2) possible land traffic interruptions in the I-5/Burlington Northern Railroad corridor as the result of a flood event. Alternative measures to minimize damages associated with these two problems will be considered and a recommended program developed.

Effects of No Action

Given no action and realization of the 550 mcy forecast, average annual flood damages of $43,411,000 can be expected. In the Feasibility Report, these damages were set at $127,504,000. The lower number with this report reflects the change in the sediment budget, the change in sediment delivery along the Cowlitz River, the change to 1985 dollars, revised safe levee heights at Longview and Kelso, and using an interest rate of 8-5/8 percent. In both estimates, once a 2-year flood overtops permanent levees, abandonment of the area is assumed and no future damages are assessed. Costs of that abandonment, e.g., to utilities and infrastructure, are not included in these estimates. If these costs were included, the need for some solution to the flooding problem would be further emphasized. Hence, the damage estimates here are conservative.

This abandonment point occurs at Castle Rock in 1987, at the I-5 and railroad bridges in 1988, at Lexington in 1991, and, finally, at Kelso in 1996. While abandonment is not projected at Longview, frequent flooding of commercial, industrial, and residential land proximate to the Cowlitz River could be anticipated with no action.

Effects with the Base Condition

Definition

Public Law 98-63 (the Supplemental Appropriations Act of 1983) authorized interim measures to protect communities along the Cowlitz River from St. Helens' blast-related flood damage. In response, the Corps has adopted a minimum level of protection, a base condition, in place of the traditional "no-action" alternative for this analysis. The base was established in the

Feasibility Report as the level of protection afforded by channel geometry as recorded in November - December 1983. This level was selected because it was: (1) documented by surveys, and (2) achievable on a continuing basis. Base level protection is that provided by permanent levees, i.e. Permanent Safe Protection (PSP). Longview has 71-year, Kelso has 3-year, Lexington has 77-year, and Castle Rock has 71-year PSP for a base standard. These figures vary from those in the Feasibility Report because they are calculated with the HEC-2 model using measurements taken in the Cowlitz River over the past five years and revised safe levee heights were used. The HEC-6 model used previously proved difficult to verify against field measurements.

Temporary Emergency Protection (TEP) as of 1982, with all interim measures implemented, including dredging, maintenance of permanent levees, and augmentation of temporary levees, was at or better than the 100-year event. However, TEP is designed primarily for one-time protection of property. Hence, by Corps standards, it cannot be considered as permanent. These standards pertain under current Federal Flood Insurance Programs.

Effects

With maintenance of the base by dredging, annual damages would be reduced to a residual of $16,505,000. The average annual cost for this reduction is put at $13,080,000. With only 3-year PSP, it is obvious that the greatest single element of these damages, $13,912,000 annually, would be at Kelso. Virtual complete inundation would occur at Kelso several times in the 1986 to 2035 period under this scenario. Minor pooling in low lying areas behind levees and inundation of unleveed areas by streamflows would characterize flooding in other areas of the Cowlitz Valley. With base condition dredging on Toutle River, damage of $1 M or more would not be accrued at the transportation corridor until a storm of 105 year recurrence interval happens. With Cowlitz River dredging, damage of $1 M or more would result from a 55-year flood.

The Columbia River

With the new forecasts, no navigation disruptions are predicted due to Mount St. Helens sediment unless low-frequency storms occur. Hence damages and

costs for dredging in the Columbia no longer contribute to either the no action or base conditions. The river is still expected to receive and transport over 500 mcy of sediment over the next 50 years. However, sediment delivery due to low probability flood events may require dredging to maintain authorized navigation channel depths.

Relationship to Feasibility Report

Three major distinctions exist between this description of the no-action and base conditions and that found in the Feasibility Report. First, minimal sediment deposition is forecast in the Columbia River, hence no disruptions to navigation are foreseen. Second, the present value of average annual losses due to flooding in the Cowlitz Valley is greatly reduced in the no-action condition. Third, most damage can be expected to occur at Kelso under this forecast, where Longview showed the greatest average annual damage previously. Longview was expected to have $102,100,000 average annual damages in the Feasibility Report, compared to Kelso's $6,100,000. The damages are now set at $3,500,000 for Longview and $20,700,000 for Kelso. The changes in these damage estimates will be discussed further in Chapter IV.

Pre-Eruption and Base Protection Levels

The pre-eruption and base protection levels provided for Longview, Kelso, Lexington, and Castle Rock are displayed on Table II-4.

TABLE II-4
PROTECTION LEVELS
(average exceedence interval, years)

	Pre-Eruption	Base Dredging w/Exist. Levees 4/
Longview	100-year 1/	71-year
Kelso	100-year 1/	3-year
Lexington	Less than 10-year 2/	77-year
Castle Rock	Greater than 100-year 3/	71-year

1/ Based on Portland District interim letter report, entitled, Drainage District Condition Study on Safe Water Surface Levels, dated May 1978. One-hundred-year PSP is the minimum level which existed. Freeboard of 10 feet (at Longview) and 5 feet (at Kelso) were not incorporated into this protection level determination (i.e., the PSP was probably greater).

2/ Inside toe of levee prior to the 1980 eruption was used as the safe height for PSP determination.

3/ Three feet below the crest of Castle Rock levee prior to the 1980 eruption was used as the safe levee height and for determination of PSP.

4/ Based on dredging level authorized by PL 98-63. This has been defined as dredging to maintain the channel geometry existing in December 1983.

CHAPTER III - DESCRIPTION AND ANALYSIS OF MEASURES

INTRODUCTION

The measures under consideration for dealing with the sedimentation and resultant flooding problems are reviewed below. Three basic possibilities are presented: (1) dredging to maintain or increase flood protection; (2) building a sediment retention structure in one stage (SRS); and (3) building a retention structure in multiple stages (MSRS). Raising existing levees is considered as an added increment to each of the three basic strategies. In the dynamic Toutle/Cowlitz system, levee improvements provide an adequate level of protection for the affected communities only if sediment aggradation in the channel stops. Once the measures are reviewed they will be combined into the complete management strategies that comprise the alternative plans. The alternatives are analyzed on economic and environmental criteria in Chapters IV and V.

DREDGING

Three dredging alternatives were analyzed: (1) minimal dredging to maintain the base condition; (2) an intermediate program which provides protection at the 100-year level for all communities except Kelso; (3) the maximum level, which provides protection above the 100-year level except at Kelso.

Anticipatory dredging, through the establishment and maintenance of Sediment Stabilization Basins (SSB), is the preferred method for maintaining protection on the Cowlitz River. The SSB slows the velocity of water by overdredging of a reach to create a sump. Consequently, bed material sediments deposit there. The SSB can be allowed to fill or maintain through additional dredging. The LT-1 site is an SSB. It has trapped nearly 13.4 mcy of sediment between water years 1981-1985 with a small sump and intensive maintenance dredging.

For Toutle River dredging, SSB's will be operated simultaneously at the LT-1, LT-3 and NF-1 sites. These three sites offer approximately 8.5 mcy of sediment detention volume at the beginning of the flood season. Depending on

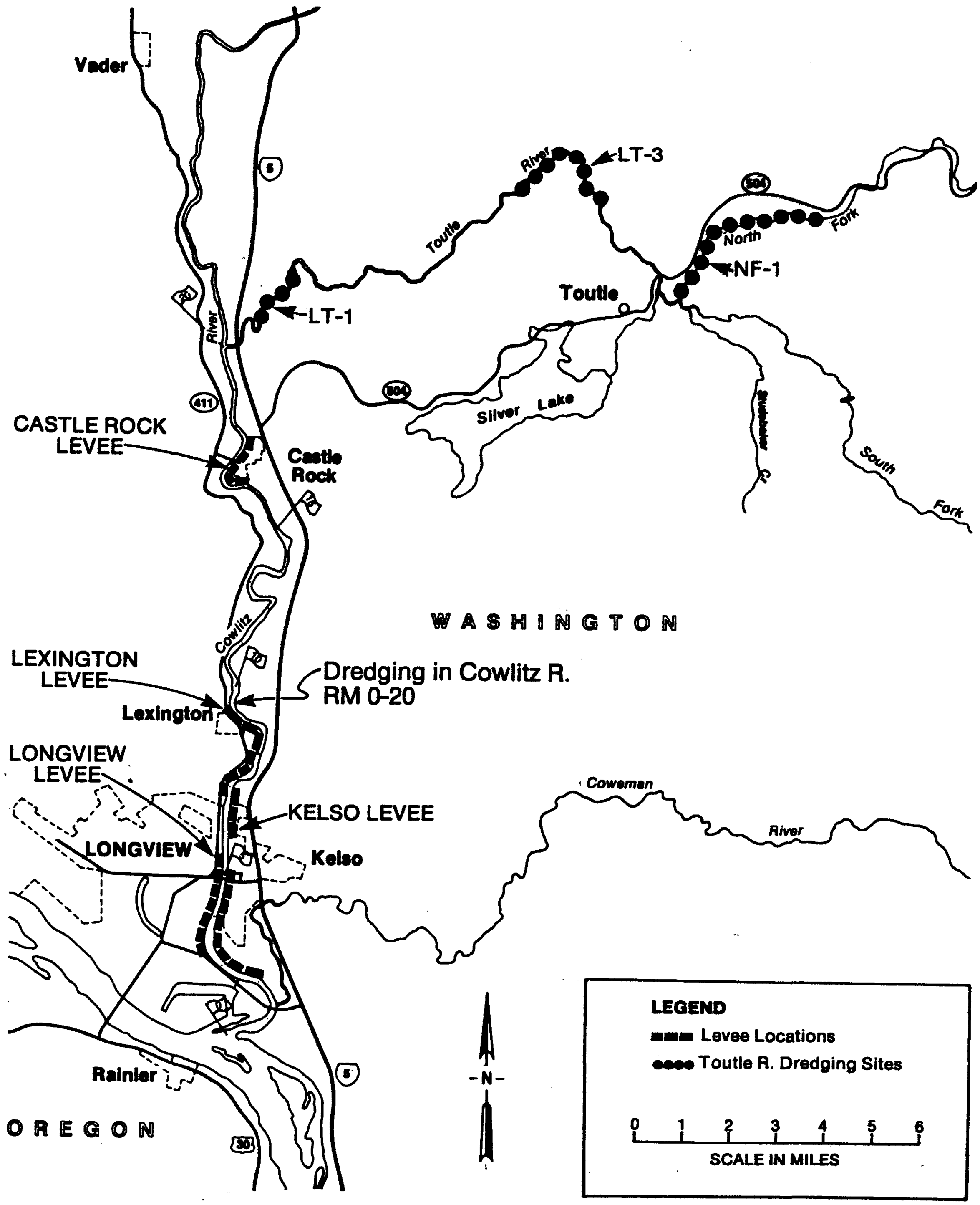


FIGURE III-1: DREDGING AND LEVEE LOCATIONS

sediment yields, an additional 10.5 mcy can be achieved through maintenance dredging for a total of 19 mcy of materials in detention and/or disposal areas during a water year. When the SSB's are dredged to their maximum capacity, they can provide protection against the sedimentation of a 100-year flood (except at Kelso).

Base Dredging

Location

Base dredging would be carried out at sites on the main stem and North Fork Toutle, particularly NF-1 between North Fork river miles (RM) 0 - 5.5, LT-3 between Toutle RM 10.4 - 13.9, and LT-1 between Toutle RM 1.9 - 3.3, until the year 2000 (see Figure III-1 for locations). At that time, cost-effective Toutle Basin disposal sites would be filled and dredging would shift to the Cowlitz River. It would continue there through 2035, with 80 percent of the material being removed from Cowlitz RM 10 - 20, 13 percent from RM 5 - 10, and 7 percent from RM 0 - 5. During that time, 92 mcy of sediment would be taken from the Toutle River and 42 mcy from the Cowlitz, if the 550 mcy budget is realized.

Levels of Protection

While dredging proceeds in the Toutle River sites, Longview has PSP against a 71-year, Kelso a 3-year, Lexington a 77-year, and Castle Rock, a 71-year flood. In 2001, when dredging moves to the Cowlitz River, these levels are changed to 71-, 3-, 59-, and 20-year protection, respectively. Toutle River dredging results in lower flood elevations along the Cowlitz River. Lower flood levels are due to the trapping of storm sediment in the Toutle, thereby preventing deposition in the Cowlitz River prior to the flood peak discharge. The amount of reduction varies with the storm size and location along the Cowlitz River. The PSP at Castle Rock is greatly decreased because most deposition during a storm occurs in this area.

Real Estate Requirements

Approximately 70 different disposal sites would be required with the base option. Total area of these sites is around 4,400 acres. These sites are adjacent or proximate to the dredging locations in the Toutle and Cowlitz Rivers.

Environmental Effects and Mitigation

Adverse environmental effects of this option include turbidity in the lower Cowlitz and Toutle River when dredging is proceeding there, mounding of dredged materials to heights of as much as 70 feet, and instability of the material mounds. Programs of mitigation, particularly ones for establishing vegetation on the mounds, are appropriate.

Cost Estimates for Base Dredging

Assuming dredging was initiated on the Toutle and later shifted to the Cowlitz River, the total cost of this base alternative would be $346,640,000 in 1985 dollars. Over the fifty year life of the project, this averages to $13,080,000 annually. A detailed breakdown of costs is presented in Table III-1.

TABLE III-1
ESTIMATED COSTS FOR BASE DREDGING
($ M of 1985 dollars)

Location	Dredging Quantity mcy	Dredging, Real Estate 1/ & Mitigation 2/	Rehab. of Disposal Sites	Bank Prot.	Mon.	Total
NF-1	53.00	115.90	3.00	3.14	7.90	129.94
LT-3	27.00	53.70	0.71	3.40	3.40	61.21
LT-1	12.20	23.80	0.68	2.80	4.50	31.78
RM 10-20	33.20	63.50	3.04	0.00	17.50	84.04
RM 0-10	9.10	19.40	2.77	0.00	17.50	39.67
TOTALS	134.50	276.30	10.20	9.34	50.80	346.64

1/ Total Real Estate Cost = 9.24

2/ Total Mitigation Cost = 22.67

AVERAGE ANNUAL COSTS: 13.08

Intermediate and Maximum Dredging

Changes in costs and protection levels with intermediate and maximum dredging are detailed in summary tables III-2 and III-3, respectively.

Summary on Dredging Measures

To summarize, base dredging has the lowest total and average annual costs, $346,640,000 and $13,080,000, of the dredging measures (see Table III-3).

TABLE III-2
COSTS OF DREDGING MEASURES
($ M of 1985 dollars)

Measure	Initial	O & M	Other	Total	Avg. Annual
Base	276.29	10.20	60.15	346.64	13.08
Intermediate	403.78	12.20	60.15	476.13	16.50
Maximum	593.43	15.40	60.15	668.98	22.08

The amount of protection increases as costs do; the maximum dredging provides the greatest protection (see Table III-3).

TABLE III-3
LEVELS OF PROTECTION (PSP) WITH DREDGING
(average exceedence intervals)

	With Toutle R. Dredging				With Cowlitz R. Dredging			
Measure	LG	KL	LX	CR	LG	KL	LX	CR
Base	71	3	77	71	71	3	59	20
Intermediate	167	11	167	118	149	10	143	63
Maximum	303	56	313	200	270	50	263	117

LEGEND:

LG = Longview LX = Lexington

KL = Kelso CR = Castle Rock

SINGLE RETENTION STRUCTURE IN ONE STAGE (SRS) DESIGNED TO 550 MCY BUDGET

Five variants of the SRS were considered. Roller compacted concrete and embankment were considered as construction for these variants. Spillway descriptions presented here are applicable in either case. Costs pertain to the construction method specified.

Location

Any selected SRS or MSRS will be located at the "Green River" site on the North Fork Toutle River, 2 miles upstream from its confluence with the Green River (see Figure III-2).

Heights

The spillway heights considered in this study are 50, 100, 125, 150, and 200 feet. These correspond to elevations 865, 915, 940, 965, and 1,015 feet NGVD.

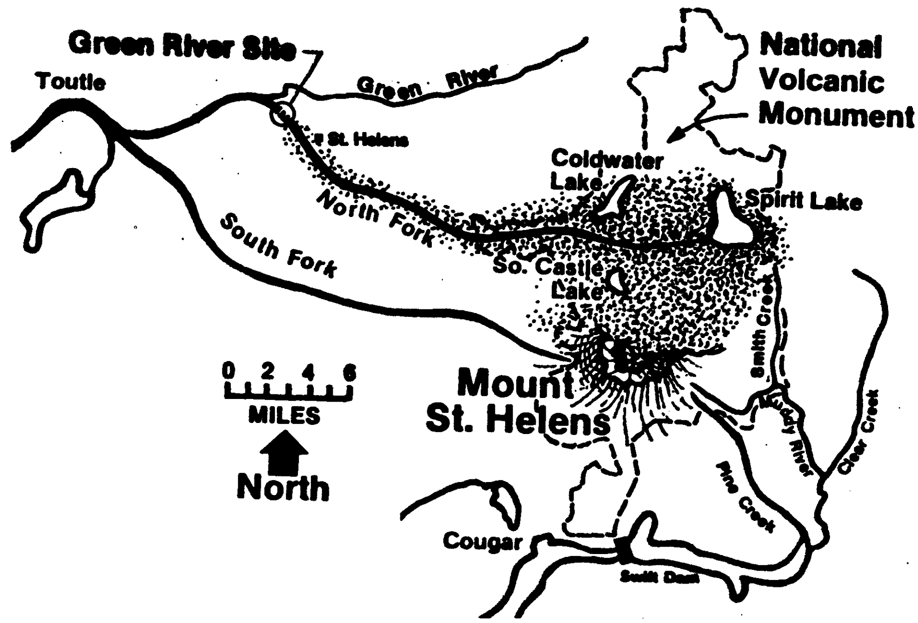


FIGURE III-2: GREEN RIVER SITE

Retention Capabilities

The sediment retention characteristics of the SRS change as sediment fills the available storage. Variations in streamflow will cause infinite changes in trap efficiency, but there will be three general phases of sediment retention as shown on Figure III-3. The first will be as the depositional surface rises toward the spillway crest. During this phase, all sediment sizes will be trapped in the reservoir area. The second phase begins when deposition reaches the spillway crest and lasts until the slope of the depositional surface is approximately one-quarter of the original stream slope (S/4). Only sand and gravel are expected to deposit during this second phase. Some sand transport through the SRS can be expected during this time. The final phase is the deposition of gravel and coarse sand, until the depositional slope is about one-half the original stream slope (S/2).

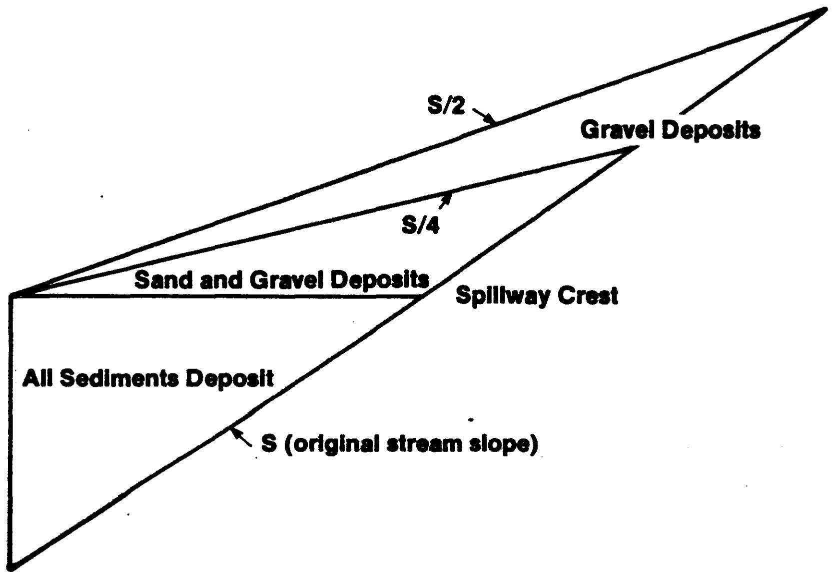


FIGURE III-3: SEDIMENT RETENTION PHASES

Table III-4 reports the sediment retention capabilities of structures with the various spillway heights. Table III-5 shows the movement of sediment through the Toutle/Cowlitz/Columbia River System with the 125 foot SRS and downstream Cowlitz dredging. The no-action sediment movement is shown in Table II-1, p. II-2.

Impoundment Areas

The area required for the impoundments of various options is shown in Table III-5. As the height of the spillway increases the area of the impoundment expands.

TABLE III-4
SEDIMENT RETENTION CAPABILITIES OF SRS'S WITH SELECTED SPILLWAY HEIGHTS

Spillway Height (ft)	Elevation (ft NGVD)	Storage Available (mcy) S 1/	S/4 2/	S/2 3/
50	865	5	19	32
100	915	25	114	161
125	940	45	190	258
150	965	79	276	435
200	1015	194	472	760

1/ Storage to spillway crest above existing ground.
2/ Infill slope where only very coarse sands, gravels, and cobbles are retained.
3/ Maximum theoretical storage.

TABLE III-5
SPILLWAY HEIGHTS AND SEDIMENT IMPOUNDMENT AREA
(acres)

Spillway Height (ft)	Area @ Spillway Crest (acres)	Area@ S/4 1/ (acres)	Area@ S/2 2/ (acres)
50	150	540	860
100	510	1500	2510
125	915	2050	3200
150	1325	2550	3825
200	2100	3500	4950

1/ Point at which only coarse sands, gravels, and cobbles are retained.
2/ Maximum storage at one-half the existing ground slope.

Levels of Protection

In the initial year of operation, all SRS options provide PSP for a 100-year event at Longview, a 4-year event at Kelso, a 91-year event at Lexington, and a 71-year event at Castle Rock. As the SRS structures fill to S/4 and then S/2, sand will be transported through the SRS and, depending on the SRS size, new sedimentation could occur downstream and protection will drop. In that event, the level of protection provided by a SRS may eventually deteriorate below that provided by base dredging without additional dredging.

A SRS would reduce or prevent storm sediment deposition in the Cowlitz River prior to a flood peak. The structure will have varying storm sediment trapping capabilities until the depositional slope reaches S/2. Below S/4, the sediment storage will be permanent. Between S/4 and S/2, storage will only be temporary. The length of time this capability exists varies with the size of the SRS. The 125-foot SRS would provide at least temporary storm sediment deposition through the entire 50 years.

Mudflow deposition is likely only in the first few years, until sediment deposition reaches the spillway crest. After that point, the behavior of mudflows is unknown.

All options will have spillways designed to pass a peak discharge of 213,000 cfs, the probable maximum flood, and a design mudflow of 228,000 cfs (75 mcy). However, the storage used by materials from a low probability event would hasten the time at which slopes of S/4 and S/2 occur. Thus large mudflows or storms can be expected to shorten the effective life of all the SRS options under average conditions.

The storage volumes remaining in the 125 foot SRS impoundment area through the project life, assuming average infill, are shown on Figure III-4.

Real Estate Requirements

Real estate requirements have been established to encompass the structure and appurtenant features, construction area, fish facilities, and sediment storage area of each spillway height studied (see Table III-6).

TABLE III-6
REAL ESTATE REQUIREMENTS

Spillway Height (ft)	Total Project (acres)	Total Real Estate Costs ($M)
50	3,407	$7.7
100	4,607	9.1
125	5,207	9.8
150	5,807	10.5
200	6,407	11.1

Environmental Effects and Mitigation

Water quality downstream from the project could be seriously impacted if water is allowed to be stored during summer and fall. To alleviate this potential problem, the multiple pipe outlets were designed to pass inflow during the warm summer months, minimizing impoundment of the river. After initial dredging, dredging would not be required for 14 years. Hence, the mitigation associated with it would not be necessary until later project years. The most substantial mitigation necessary with an SRS is bypass facilities for migrations of anadromous fish.

Cost Estimates

The total cost estimates in Table III-7 are broken into three categories: 1) Construction; 2) Dredging; and 3) Other. Construction includes the construction costs for the SRS and the related monitoring, real estate, relocation, and mitigation costs. Dredging includes both initial and outyear costs, real estate acquisition costs, and mitigation costs associated with dredging. The other category includes expenditures for rehabilitation of other works impacted by the plan and general monitoring. Detailed breakdowns are reported in Appendix B.

REMAINING SEDIMENT STORAGE BY WATER YEAR

940 FEET NGVD SEDIMENT RETENTION STRUCTURE
SAND AND COARSE SEDIMENTS

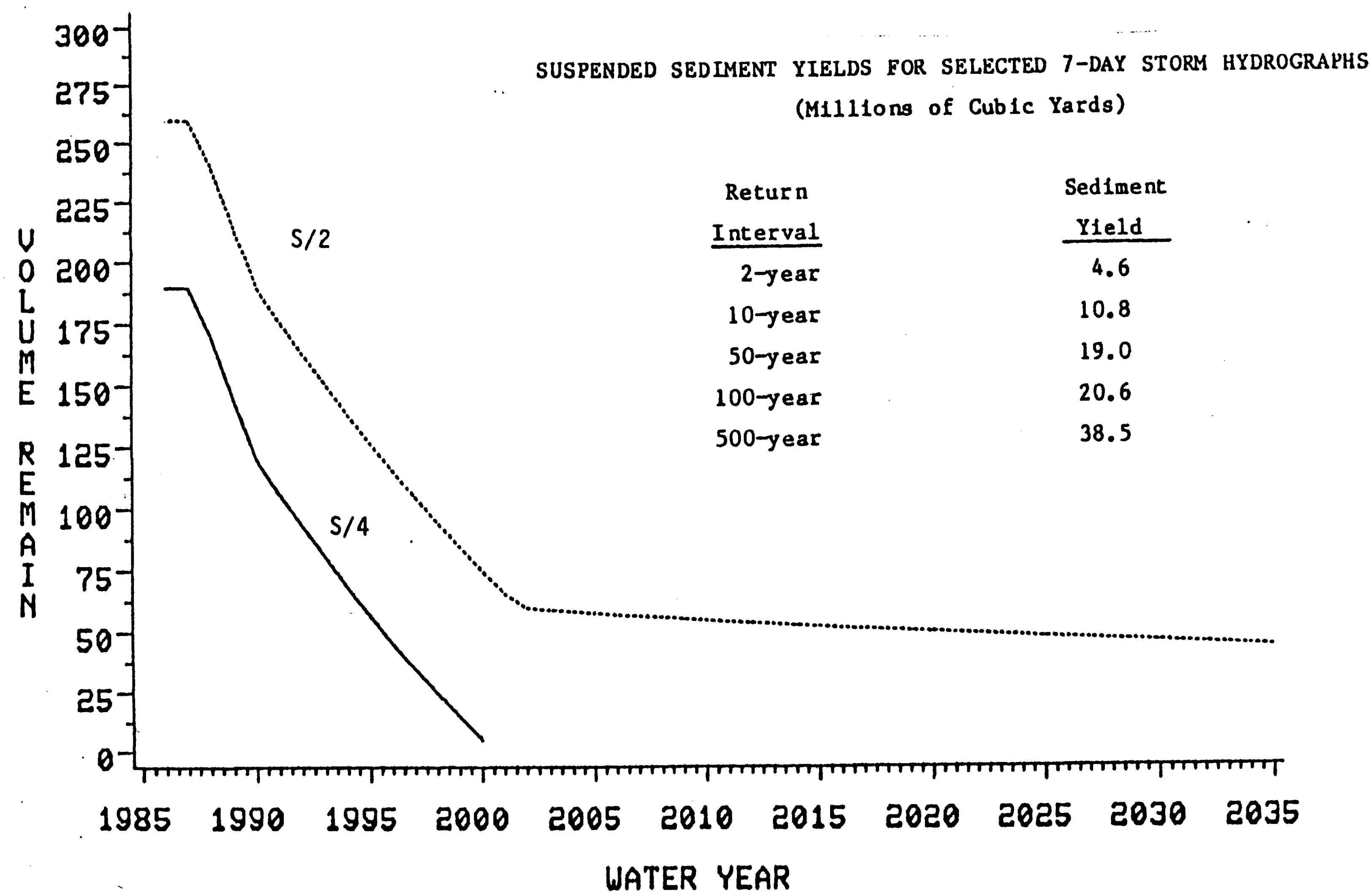


FIGURE III-4: REMAINING SEDIMENT STORAGE BY WATER YEAR

TABLE III-7
COSTS OF SRS'S WITH SELECTED SPILLWAY HEIGHTS AND DOWNSTREAM DREDGING PROGRAMS
($ M 1985)

Spillway Ht (ft)	SRS Construction ($ M)	Dredging ($ M)	Other ($ M)	Total ($ M)	Average Annual ($ M)
EMBANKMENT WITH TOUTLE DREDGING					
50	85.70	171.81	60.05	317.56	11.89
100	93.80	94.28	51.15	239.23	9.45
125 (940 NGVD)	98.90	63.64	43.80	206.34	8.62
150	112.10	41.78	30.30	184.18	9.09
200	143.50	22.08	4.3	169.88	11.62
EMBANKMENT WITH COWLITZ DREDGING					
50	86.90	229.60	63.90	380.40	11.79
100	93.80	89.13	50.60	233.53	8.76
125 (940 NGVD)	98.90	58.32	44.60	201.82	8.15
150	112.10	34.77	30.90	177.77	8.70
200	143.50	17.36	4.30	165.16	11.25
CONCRETE GRAVITY WITH TOUTLE DREDGING					
50	80.9	171.81	60.05	312.56	12.09
100	99.8	94.28	51.15	245.23	10.35
125 (940 NGVD)	109.8	63.64	43.80	217.34	9.86
150	123.1	41.78	30.30	195.18	10.24
200	165.5	22.08	4.30	199.88	13.32
CONCRETE GRAVITY WITH COWLITZ DREDGING					
50	80.9	229.60	63.90	374.40	11.89
100	99.8	88.95	50.60	239.35	9.65
125 (940 NGVD)	109.9	59.08	44.60	213.58	9.40
150	123.1	34.77	30.90	188.77	9.86
200	165.5	17.36	4.30	187.16	12.95

In general, the embankment structures are less expensive than comparable roller-compacted concrete ones. The 940 NGVD (125 foot spillway) embankment structure shows the lowest average annual cost of $8,150,000. References to Toutle dredging mean that initially dredging will be along Toutle River. When cost-effective disposal sites are full there, dredging will be shifted to Cowlitz River. References to Cowlitz dredging mean dredging will be along Cowlitz River until cost-effective disposal sites are filled, then dredging will shift to Toutle River.

MULTI-STAGED RETENTION STRUCTURE (MSRS) DESIGNED TO THE 550 MCY FORECAST

Two configurations were considered for a multi-staged single retention structure (MSRS): (1) two stages and (2) three stages. These options were analyzed in four staging alternatives. Only embankment construction was analyzed. As with the SRS, the Green River site is the proposed location for the project.

Height of Foundation Stage

The greatest benefits for staging would accrue if only the foundation stage was required. Assuming that half of the current estimated budget (E) is the minimum future erosion that might reasonably be expected, the foundation must then be capable of retaining 1/2 E for greatest possible effectiveness. The 100 foot spillway structure (915 NGVD) was the lowest cost configuration with that capacity. Hence, that is the height of the foundation stage in the four scenarios depicted in Figure III-5.

Two-Stage Height

A two-stage structure adds one additional increment of 25 feet to the foundation stage. As the stages are executed the spillway raises from 100 feet. Note that this spillway height of 125 feet was the least cost height for the SRS.

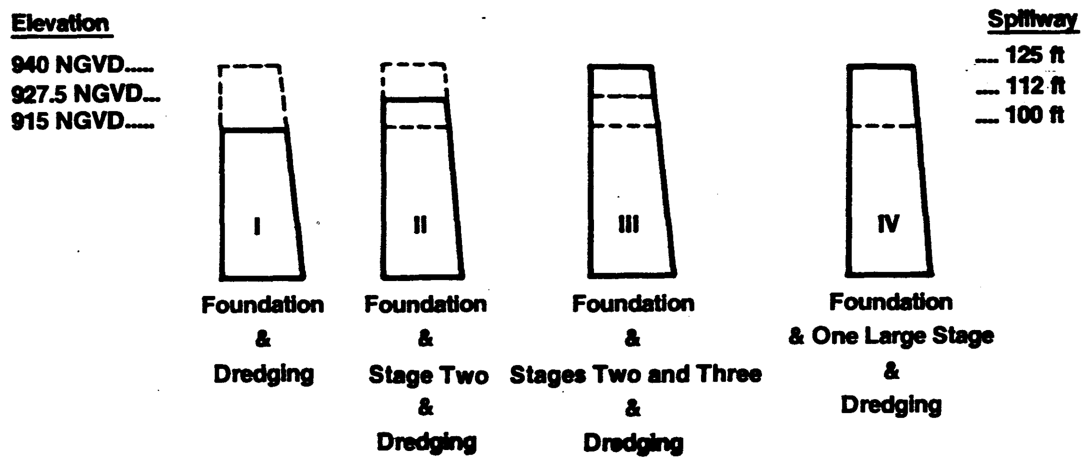


FIGURE III-5: MSRS STAGING SCENARIOS

Three-Stage Height

A three-stage structure adds two additional increments of 12.5 feet to the foundation stage. As the stages are executed, the spillway raises from 100 feet to 112.5 feet, and, finally 125 feet. Rises past 125 feet would call for additional foundation construction and increase costs of the structure.

Height Beyond 125 Feet

Adding stages beyond the 125-foot level were briefly investigated. From preliminary investigations, it may be slightly cheaper (in average annual cost terms) to add a stage to the 150-foot or 200-foot spillway than to incur outyear dredging costs after the 125-foot SRS fills in.

Retention Capabilities

Staging of a MSRS results in the same reservoir retention capabilities for a given spillway height as a SRS. Table III-8 reiterates these values for the MSRS heights.

TABLE III-8
SEDIMENT RETENTION CAPABILITIES WITH STAGING

Spillway Height (ft)	Retention at Spillway Crest (mcy)	At S/4 (mcy)	At S/2 (mcy)
100	25	114	161
112.5	34	129	209
125	45	190	258

Reservoir Area

Reservoir areas are likewise similar to the SRS. Table III-9 reports them with stages.

TABLE III-9
RESERVOIR AREAS OF STAGES

Spillway Height (ft)	Spillway Crest (acres)	Sediment Retention at S/4 (acres)	Sediment Retention at S/2 (acres)
100	510	1500	2510
112.5	680	1800	2880
125	915	2050	3200

Levels of Protection/Low Probability Event Protection

Staging has no effect on permanent levels of protection, assuming increments are executed in proper sequence. If retention, after all stages are in place, is not adequate, downstream dredging will be necessary to maintain protection. If low probability events occur while the reservoirs still have capacity, substantial protection against these events is afforded. Deposits may erode later but will be removed from the event discharge. This protection is renewed as new stages are constructed.

Real Estate Requirements

Real Estate requirements for the SRS alternative have been established to encompass the structure and other appurtenant structures, construction area, fish facilities, and sediment storage area. If staging is authorized, final real estate acquisition will be determined based on the final stage authorized for project purposes.

Environmental Effects and Mitigation

As with the SRS, programs are necessary for migration of fish into the upper Toutle Valley and dredging mitigation in the outyears.

Cost Estimates

With staging, four scenarios are possible: (1) construction of the foundation stage only, resulting in a 100-foot spillway structure; (2) execution of two of the three stages in a three-stage configuration, for a spillway of 112.5 feet operational in 1996; (3) execution of three of three stages, for a 125-foot spillway operational in 2003; and (4) building a 125-foot spillway in two stages to be operational in 1996 (see Figure III-3). Table III-10 depicts the costs for these MSRS possibilities. These dollar estimates were calculated in the same way as for the SRS options.

The least-cost alternative is a two-stage embankment MSRS with both stages executed with dredging in the Cowlitz River first.

LEVEE IMPROVEMENTS

Each of the four lower Cowlitz River communities, Longview, Kelso, Lexington, and Castle Rock, have existing levees (see Figure III-1, p. III-2) affected by levee raise options. Raises could be done at each location, all of them, or any combination of them. Three levels of improvement are considered. The minimum improvements bring current levees up to Corps' standards and only increase height incidental to that action. The second and third options are designated "medium" and "high" raises.

TABLE III-10
COSTS OF MSRS SCENARIOS
($ M 1985)

EMBANKMENT WITH TOUTLE DREDGING

Scenario	Structure	Downstream Dredging	Other	Total	Average Annual
1 (I)	99.80	94.28	51.15	245.23	9.86
2 (II)	100.95	82.96	48.40	232.31	9.53
3 (III)	99.96	69.17	41.20	210.33	9.17
4 (IV)	99.80	66.67	40.20	206.67	8.97

EMBANKMENT WITH COWLITZ DREDGING

Scenario					
1 (I)	99.80	91.01	50.60	241.41	9.16
2 (II)	100.95	79.91	50.80	231.66	8.98
3 (III)	99.96	61.84	44.80	206.60	8.61
4 (IV)	99.80	59.62	43.70	203.12	8.45

Levels of Protection

Levels of protection cannot be attached to levees alone. Without a retention structure or dredging to maintain channel geometry, levels of protection would constantly decrease. They will be reported with the combination plans reviewed later in this chapter.

Real Estate Requirements

All options would require land acquisition with some relocation of businesses or homes. Under the medium or high options, some highway relocation would be required.

Environmental Effects and Mitigation

The levees themselves have little effect on the environment. They exist in places of urban development, hence wildlife habitat is not affected. Even disruptions to human environments are for the most part limited to construction phases of the levees. Some structures would be impacted for all levee raises considered.

Cost Estimate

Table III-11 shows the costs of each of the possible levee measures at each Cowlitz community.

TABLE III-11
COSTS OF LEVEE IMPROVEMENTS
($ M 1985)

	Longview			Kelso		
	Minimal	Medium	High	Minimal	Medium	High
Construction	0	5.40	10.70	0.77	5.40	13.30
Real Estate	0	28.10	28.10	1.10	15.00	15.00
Total	0	33.50	38.80	1.87	20.40	28.30
Avg Annual Costs	0	2.27	2.63	0.14	1.39	1.39

	Lexington			Castle Rock		
	Minimal	Medium	High	Minimal	Medium	High
Construction	0.56	3.20	5.70	0.20	0.35	2.05
Real Estate	0.78	2.00	2.00	0.18	3.65	3.65
Total	1.34	5.20	7.70	0.38	4.00	5.70
Avg Annual Costs	0.10	0.35	0.52	0.03	0.27	0.38

MANAGEMENT STRATEGIES

The measures presented to this point are not necessarily individually viable or optimal strategies as they stand. Combinations of them are among the plan

alternatives directly considered in this report. The plan alternatives include dredging alone, dredging with levee raises, SRS's, MSRS's, and SRS's with levee raises. No MSRS had lower costs than an SRS of the same spillway height, hence MSRS's with levee raises are not evaluated. All of the SRS's and MSRS's under consideration require downstream dredging initially and in the outyears, hence all retention structure strategies are inherently combinations of a structure and dredging. Table III-12 enumerates the alternatives. If they were previously reviewed, the location of that discussion is noted. This section details only those not previously covered.

TABLE III-12
MANAGEMENT STRATEGIES REVIEWED

Strategy	Reviewed in Chapter III at Pages:
1. Base Dredging	III-3 to III-5
2. Intermediate Dredging	III-5 to III-6
3. Maximum Dredging	III-5 to III-6
4. SRS/outyear downstream dredging	III-6 to III-14
5. MSRS/outyear downstream dredging	III-14 to III-17
6. Levee Improvements	III-17 to III-20
7. Base Dredging with Minimum Levee Improvements	III-21 to III-23
8. Base Dredging with Medium Levee Raises	III-22 to III-23
9. Base Dredging with High Levee Raises	III-22 to III-23
10. Intermediate Dredging with Minimum Levee Improvements	III-22 to III-23
11. SRS with Minimum Levee Improvements, Base Initial and Outyear Dredging	III-23 to III-24
12. SRS with Minimum Levee Improvements, Base-Plus Initial and Outyear Dredging	III-24 to III-25

DREDGING/LEVEE IMPROVEMENT COMBINATIONS UNDER THE 550 MCY FORECAST

Ten combinations of dredging with levee raises are reviewed as possible management strategies. Table III-13 shows them. Combinations of intermediate dredging and medium or high levee raises were not considered because of their high costs and limited improvements in protection.

TABLE III-13
LEVEE RAISE/DREDGING MEASURES CONSIDERED

	Levee Raises					
	Minimal				Medium	High
Dredging	KL	KL,LX	KL,CR	KL,LX,CR	KL,LX,CR	KL,LX,CR
Base	X	X	X	X	X	X
Intermediate	X	X	X	X	0	0

LEGEND:

X = Considered
0 = Not Considered

KL = Kelso
LX = Lexington
CR = Castle Rock

Levels of Protection

With minimal improvements and base dredging, Longview has 71-year, Kelso (KL) has 70-year, Lexington (LX) has 125-year, and Castle Rock (CR) has 91-year PSP during the Toutle River dredging period. From 2001, when dredging is in the Cowlitz River, this reduces, respectively, to 71-, 56-, 111-, and 33-year protection. With minimal raises and intermediate dredging, the comparable Toutle dredging numbers are 167-, 143-, 233-, and 133-year PSP; Cowlitz dredging results in 149-, 139-, 192-, and 71-year levels. The medium and high raises, respectively, provide 100- and 500-year protection with base dredging.

Total costs are represented in Table III-14. The average annual costs for these options are reported as part of the economic analysis in Chapter IV. In general, the costs reported in Table III-11, those for the levees themselves, are initial costs. They would be incurred in 1986 and 1987.

TABLE III-14
COSTS OF LEVEE RAISE/DREDGING MEASURES
($ M 1985)

	Levee Raises					
Dredging	Minimal				Medium	High
	KL	KL,LX	KL,CR	KL,LX,CR	KL,LX,CR	KL,LX,CR
Base	348.51	349.85	348.89	350.23	409.74	427.14
Intermediate	478.72	479.34	478.38	479.72	1/	1/

1/ Option not considered.

Reduction Caused by 10-Year Flood

Sediment deposition from large flood events can be expected to cause temporary reductions in the levels of protection. The length of time and the size of the reduction will depend on the magnitude of the flood. A 10-year frequency flood is likely to occur several times during the 50-year project period. If it occurred between 1986 and 2000, it would deposit sediment in the Toutle River sumps and greatly reduce their capacity to handle any subsequent events. Under the base dredging with minimal levee improvement alternative, this would cause the levels of protection at Lexington to fall from 125-year to 111-year and those at Castle Rock to fall from 91-year to 33-year, until the Toutle River sumps were restored to full capacity. This would not cause a noticeable change in the levels of protection at Longview (71-year) or Kelso (70-year) because of the expected Cowlitz deposition pattern (Appendix A). Should a 10-year flood occur after 2000 (when dredging is being done in the Cowlitz River), 3 mcy of deposition would occur in the Cowlitz River, mostly

upstream from RM 5. The result would again be no noticeable reduction in levels of protection at Longview and Kelso, but temporary reductions at Lexington from 111-year to 102-year and at Castle Rock from 33-year to only 13-year protection.

SRS WITH MINIMUM LEVEE IMPROVEMENTS AND OUTYEAR DREDGING FOR BASE CHANNEL GEOMETRY

The 125-foot spillway (940 NGVD) SRS, with associated dredging, was considered in combination with minimal levee improvements at 1) Kelso; 2) Kelso and Lexington; 3) Kelso, Lexington and Castle Rock; and 4) Kelso and Castle Rock. Longview's current levees are considered adequate in this analysis, hence are not improved beyond current levels. Initial and outyear dredging to maintain base condition channel geometry would remove 32 mcy of sediment from the Cowlitz River.

Levels of protection are improved over the 125 foot SRS without levee improvements. Particularly, substantial added protection occurs at Kelso. For example, the 125-foot SRS with levee improvements at Kelso and Castle Rock shows 100-year protection at Longview, 77-year at Kelso, 91-year at Lexington, and 91-year at Castle Rock. Again the SRS maintains the channel against an low probability event as long as it has reservoir capacity.

Costs

Table III-15 shows the total and annual average costs of SRS/dredging/levee improvement alternatives.

TABLE III-15
COSTS OF SRS/LEVEE IMPROVEMENT/DREDGING FOR BASE GEOMETRY STRATEGY
($ M 1985)

Levee Improvements at	Initial Costs	O&M	Other Costs	Total	Average Annual
Kelso	137.79	28.10	37.80	203.69	8.29
Kelso, Lexington	139.13	28.10	37.80	205.03	8.39
Kelso, Castle Rock	138.17	28.10	37.80	204.07	8.32
Kelso, Lexington & Castle Rock	139.51	28.10	37.80	204.07	8.32

SRS WITH MINIMUM LEVEE IMPROVEMENTS AND BASE PLUS DREDGING

Finally, this SRS, levee improvement, and dredging strategy can be done with an increment of dredging beyond what is needed to maintain base channel geometry. This was considered to evaluate the costs (and in Chapter IV, the benefits) of dredging greater volume than base dredging, but less than intermediate dredging. We have termed this level of dredging as base-plus. This plan includes the 125 foot SRS, minimum levee improvement at Kelso, but requires more dredging in the Cowlitz River in intial and outyears. An additional 12 mcy of sediment is removed, for a total of 44 mcy of dredged materials on disposal sites.

Levels of protection are substantially improved by this greater dredging. Longview has 167-year, Kelso 143-year, Lexington 167-year, and Castle Rock 118-year protection with this strategy.

Costs

Table III-16 shows the total and average annual costs for this option. The incremenal cost for the greater dredging averages $1,600,000/yr over those for the SRS/levee improvement/dredging plan which provides protection for base channel geometry only.

TABLE III-16
COSTS OF SRS/LEVEE IMPROVEMENT/BASE-PLUS DREDGING STRATEGY
($M 1985)

Levee Improvements @	Initial Costs	O&M	Other Costs	Total	Average Annual
Kelso	165.16	28.10	37.80	231.06	9.38
Kelso, Lexington	167.01	28.10	37.80	232.91	9.48
Kelso, Castle Rock	166.05	28.10	37.80	231.95	9.41
Kelso, Lexington, and Castle Rock	170.67	28.10	37.80	236.57	9.51

SUMMARY

Costs of all plan alternatives considered here are presented in Table III-17. Levels of protection appear in Table III-18. The most cost-efficient strategy is identified in the next chapter. The possible strategies, however, provide varying levels of protection.

TABLE III-17
COST SUMMARY
($ M 1985)

Alternative	Initial Costs	O&M1/	Other Costs	Total	Average Annual
Base Dredging	276.29	10.20	60.15	346.64	13.08
Intermediate Dredging	403.78	12.20	60.15	476.13	16.50
Maximum Dredging	593.43	15.40	60.15	668.98	22.08
Base Dredging and Min. Levees at:					
KL, LX, CR	279.88	10.20	60.15	350.23	13.35
KL	278.16	10.20	60.15	348.51	13.22
KL,LX	279.50	10.20	60.15	349.85	13.32
KL, CR	278.54	10.20	60.15	348.89	13.25
Intermediate Dredging with Min. Levees at:					
KL,LX,CR	407.37	12.20	60.15	479.72	16.77
KL	405.65	12.20	60.15	478.72	16.64
KL,LX	406.99	12.20	60.15	479.34	16.74
KL,CR	406.03	12.20	60.15	478.38	16.67
Base Dredging & Med. Levees	339.36	10.20	60.15	409.71	17.24
Base Dredging & High Levees	356.76	10.20	60.15	427.11	18.54
SRS/Base Dredging2/					
Spillway: 50 ft	291.20	40.40	48.80	380.40	11.79
100 ft	159.70	32.00	41.80	233.50	8.76
125 ft	135.98	28.10	37.80	201.88	8.15
150 ft	129.37	21.60	26.80	177.77	8.70
200 ft	143.46	19.90	1.80	165.16	11.25
MSRS2/, Scenario					
I	173.41	26.20	41.80	241.41	9.16
II	157.66	32.20	41.80	231.66	8.98
III	140.50	29.30	36.80	206.60	8.61
IV	138.12	29.20	35.80	203.12	8.45
125 ft. SRS/Base Dredging1/ w/Levee Improvements at:					
KL, LX, CR	139.51	28.10	37.80	205.41	8.42
KL	137.79	28.10	37.80	203.69	8.29
KL, LX	139.13	28.10	37.80	205.03	8.39
KL,CR	138.17	28.10	37.80	204.07	8.32
125 ft. SRS/Base-Plus Dredging3/ w/Levee Improvements at:					
KL, LX, CR	170.67	28.10	37.80	236.57	9.51
KL	165.16	28.10	37.80	231.06	9.38
KL, LX	167.01	28.10	37.80	232.91	9.48
KL, CR	166.05	28.10	37.80	231.95	9.41

1/ Insignificant for levees. $10,000 to $20,000 per year depending upon length of levee and mechanical equipment incorporated.
2/ Embankment structure with Cowlitz River dredging.
3/ Includes O&M costs for levees.

TABLE III-18
PROTECTION LEVELS
(average exceedance interval in years)

Alternative	Longview	Kelso	Lexington	Castle Rock
1. Base Dredging	71[1]/	3	77	71
	(71)[2]/	(3)	(59)	(20)
2. Intermediate Dredging	167	11	167	118
	(149)	(10)	(143)	(63)
3. Maximum Dredging	303	56	313	200
	(270)	(50)	(263)	(117)
4. Base Dredging & Min. Levees @:				
KL, LX, CR	71	70	125	91
	(71)	(56)	(111)	(33)
KL	71	70	77	71
	(71)	(56)	(59)	(20)
KL,LX	71	70	125	71
	(71)	(56)	(111)	(20)
KL, CR	71	70	77	91
	(71)	(56)	(59)	(33)
5. Inter. Dredging w/Min. Levees @:				
KL,LX,CR	167	143	233	133
	(149)	(139)	(192)	(71)
KL	167	143	167	118
	(149)	(139)	(143)	
KL,LX	167	143	233	118
	(149)	(139)	(192)	(63)
KL,CR	167	143	167	133
	(149)	(139)	(143)	(71)
6. Base Dredging and Med. Levees	100+	100+	100+	100+
7. Base Dredging and High Levees	500+	500+	500+	500+
8. SRS Base Dredging[3]/ Spillway: 50 ft, 100 ft, 125 ft, 150 ft, 200 ft	100	4	91	71
9. MSRS[3]/, Scenario I, II, III, IV	100	4	91	71
10. 125 ft. SRS/Base Dredging[3]/ w/Levee Improvements at:				
KL, LX, CR	100	77	133	91
KL	100	77	91	71
KL, LX	100	77	133	71
KL, CR	100	77	91	91
11. SRS/Base-Plus Dredging[3]/ w/Levee Improvements at:				
KL, LX, CR	167	143	233	133
KL	167	143	167	118
KL, LX	167	143	283	118
KL, CR	167	143	167	133

1/ With Toutle River dredging.
2/ With Cowlitz River dredging.
3/ With Cowlitz River outyear dredging.

CHAPTER IV - EVALUATION OF ALTERNATIVES

The purpose of this chapter is to present the economic evaluation of the alternative plans under consideration and identify the national economic development (NED) plan among them. The new sediment forecast results in damage estimates different from those used for comparable analysis in previous documents. Also, the exact set and nature of alternatives has evolved, e.g., current spillway dimensions for an SRS vary from those considered in the Feasibility Report, and, thus, their associated costs are changed. Hence, these figures supercede any given previously and previous NED designations should be put aside.

The NED plan will be considered for sensitivity to possible future departures in sediment yield from the current sediment estimate of 550 mcy over the 50 year project life. All figures presented in this chapter are stated at a 1985 price level using the current Federal interest rate of 8-5/8 percent. Revised safe levee heights were adopted for this report. Temporary emergency protection (TEP) measures in place were not considered in this analysis since these were designed primarily to protect property on a one-time basis. The measures evaluated include dredging, an SRS and an MSRS. Levees require dredging or a SRS to maintain the channel geometry and their effectiveness. For this reason, levees are combined with each of the measures that maintain channel geometry to form alternative plans.

PRODUCTS OF THE BASE CONDITION, ASSUMING THE 550 MCY FORECAST

Damages with No Action

The Feasibility Report contained an estimate of average annual flood damages of $127,504,000 with no action for a period of 50 years commencing in 1984. Using 1985 dollars, the current discount rate of 8-5/8 percent, 1985 safe levee heights and the sediment forecast contained in the Feasibility Report, the value of these damages would be $66,852,000. Using the current 550 mcy sediment forecast, 1985 dollars and safe levee heights, and the 8-5/8 interest rate, the average annual damages with no action are estimated at $43,411,000. Maintaining the base condition at an annual cost of $13,080,000, reduces these residual damages to $16,505,000.

A detailed breakdown of the potential damages is given in Table IV-1. To reiterate, this base action establishes 71-year protection (PSP) at Longview, 3-year at Kelso, 77-year at Lexington, and 71-year at Castle Rock. Benefits for all subsequent management strategies are the difference between the average annual base condition residual damages and the residual damages with the measure being considered (in place).

TABLE IV-1
AVERAGE ANNUAL DAMAGES (AAD) WITH
NO ACTION AND MAINTENANCE OF BASE
($000)

Location	No Action 1/	No Action 2/	Base 2/
Longview (RM 5.5)	$102,109	$ 3,537	$ 180
Kelso (RM 5.5)	6,145	20,693	13,912
Lexington (RM 9.2)	4,002	2,645	273
Castle Rock (RM 17.6)	1,849	1,372	419
Transportation (RM 19.4)	12,233	14,310	132
Unleveed Areas	1,166	854	1,589
TOTAL DAMAGES	$127,504	$43,411	$16,505

1/ As reported in the Feasibility Report. Figured with 1984 dollars, 1984 safe levee heights, and discounted at 8-1/8 percent.

2/ Calculated with 1985 dollars, 1985 safe levee heights, discounted at 8-5/8 percent, and current sediment budget.

Note that once a two-year flood overtops a levee and/or inundates an area, additional damages are not assessed. In the no action scenario, this begins to occur in 1987 at Castle Rock, 1988 at the I-5 and railroad bridges (Cowlitz RM 19.4), 1991 at Lexington, and 1996 at Kelso. Flood inundation becomes so frequent at this point that abandonment is presumed. No costs are included in the average annual damages for abandonment. However, costs for items such as abandonment of utilities, removal or relocation of structures, relocation of residents, and restoration of the abandonment area are sure to occur. While

abandonment is never projected for Longview, regular flooding of commercial, industrial, and residential land proximate to the Cowlitz River could be anticipated with no action.

Products of Base Condition

While no location has less than a 2-year level of safe protection with the maintenance of the base condition, average annual damages of about $14 million can be expected at Kelso. The damages in unleveed areas increase as compared to no action, and the transportation corridor receives $132,000 in average annual damages. In the no action scenario, when flooding is severe enough, the communities are abandoned and no more damages accrue. With base dredging, even though communities and unleveed areas are damaged by floods, it is assumed they are not abandoned and continue to incur periodic damage throughout the 50 year project life. Because of this repeated inundation, damages to the unleveed areas increase when the base condition is maintained. With no action, these areas are abandoned early and no further damages are assessed.

OUTPUTS OF ALTERNATIVES

Dredging Alternatives

Three dredging only alternatives are considered here: (1) maintenance of the base condition, (2) an intermediate level of dredging, 125 percent of the base volume, and (3) maximum dredging, 150 percent of the base volume. Table IV-2 depicts the costs, benefits, and residual damages with the three options.

Of the dredging only alternatives, maintenance of base shows a substantial net benefit compared to no action. However, because of PL 98-63, this level of protection is considered as given. Alternatives can be recommended only insofar as they reduce residual damages beyond those left after implementing the base condition or lower the costs of maintaining the base condition. In this light, there are effectively only two choices here, intermediate and maximum dredging. Of the two, intermediate dredging shows the greater increment of net benefit over base, $7,912,000 to $6,202,000. It also

TABLE IV-2
AVERAGE ANNUAL RESIDUAL DAMAGES AND INCREMENTAL COST OF
DREDGING ALTERNATIVES
($000)

Location	Base Dredging 1/	Intermediate Dredging 2/	Maximum Dredging 2/
Longview	$ 180	$ 28	$ 4
Kelso	13,912	3,895	727
Lexington	273	100	31
Castle Rock	419	195	89
Unleveed Areas	1,589	888	417
Transportation	132	67	35
TOTAL RESIDUAL DAMAGES	$ 16,505	$ 5,173	$ 1,303
BENEFITS	NA	11,332 3/	15,202 3/
COSTS	13,080	3,420	9,000
NET BENEFITS	NA	$ 7,912	$ 6,202
BENEFIT/COST RATIO	NA	3.31	1.69

1/ Other alternatives are compared to this base condition. When this level of dredging is compared to the "no action" condition, the benefits are $26,906,000 (BCR is 2.06)

2/ Increment as compared to base dredging

3/ Reduction in residual flood damages from the base condition

provides substantially better levels of flood protection than base maintenance.

Dredging and Levee Raise Alternatives

Levee improvements are considered in this analysis for the four lower Cowlitz River communities: (1) Longview, (2) Kelso (KL), (3) Lexington (LX), and (4) Castle Rock (CR). Four combinations of minimal levee improvements were studied: (1) improvements at three locations (KL, LX, CR); (2) at KL only; (3) at KL and LX; and (4) at KL and CR. The Longview levee is already at Corps of Engineers standards, hence is not included in the minimal improvement actions. These minimal improvement combinations are considered with base and

intermediate dredging. The minimal levee raise is primarily action to bring existing levees to Corps standards. Some low spots will be raised in the process, but general increases in height are not implicit to this minimal option. The minimal rases are expected to be completed by 1987. Medium and high raises with base dredging are also considered. Other combinations of levee raise and dredging were not cost effective. Medium and high levee raises involve general height increases. Although substantial new construction would be necessary for the medium and high options, it was assumed that any levee improvements or raise in Kelso would be completed in 1987. Remaining medium and high raises would come in 1988.

Details on the minimal raises in combination with base dredging are presented in Table IV-3. Table IV-4 shows the incremental costs and benefits for medium and high levee raises over minimal levees. The minimal raises with intermediate dredging are in Table IV-5. Of all the options the greatest net benefits, $12,041,000 per year, are realized through minimal levee raises at Kelso, Lexington, and Castle Rock with base dredging. Again it must be kept in mind here that the average annual costs reported with this option, $270,000, are an increment added to the base dredging costs of $13,080,000. Annual average costs for it compared to no action are $13,350,000. The costs of each levee plan are presented in Table III-11.

One Stage Single Retention Structure (SRS) Alternatives

As detailed in Chapter III, five spillway heights were considered for a SRS, 50, 100, 125, 150, and 200 feet. The details of costs, benefits, and benefit/cost ratios (BCR) for them are presented in Table IV-6. The 125-foot (940 NGVD) option emerges as being both the least costly and having the greatest net benefits. Thus, a SRS with a spillway height of 125 feet at the Green River site and base dredging is the option for further analysis. The economics of that option together with the various combinations of minimal levee improvement, (1) KL, LX, CR, (2) KL, (3) KL, LX, and (4) KL, CR, are reported in Table IV-7. The SRS with downstream dredging to maintain the base channel in outyears and minimal levee improvements at Kelso produce the greatest net benefits of these options, an average of $17,438,000 annually.

TABLE IV-3
RESIDUAL DAMAGES AND INCREMENTAL COST OF
LEVEE RAISE ADDED TO BASE DREDGING
($000)

Location	Minimal Raise at: KL,LX,CR	KL	KL,LX	KL,CR
		RESIDUAL DAMAGES		
Longview	180	180	180	180
Kelso	1,846	1,846	1,846	1,846
Lexington	165	273	165	273
Castle Rock	282	419	419	282
Unleveed	1,589	1,589	1,589	1,589
Transportation	132	132	132	132
TOTAL RESIDUAL DAMAGES	4,194	4,439	4,331	4,302
		BENEFITS AND COSTS		
BENEFITS	12,311	12,066	12,174	12,203
COSTS	270	140	240	170
NET BENEFITS	12,041	11,926	11,934	12,033
BCR	45.60	86.19	50.73	71.78

TABLE IV-4
INCREMENTAL COSTS AND BENEFITS OVER THE MINIMAL LEVEES
FOR MEDIUM AND HIGH LEVEE RAISES
($000)

	Medium Levee			High Levee		
	Benefits	Costs	Net Benefits	Benefits	Costs	Net Benefits
Longview	66	2,270	- 2,204	152	2,630	-2,478
Kelso	442	1,390	-948	679	1,930	-1,150
Lexington	84	250	-166	126	420	-294
Castle Rock	149	240	-91	242	350	-108

TABLE IV-5
RESIDUAL DAMAGES AND INCREMENTAL COST OF MINIMAL
LEVEE RAISES ADDED TO INTERMEDIATE DREDGING
($000)

	Minimal Raises at:			
Location	KL,LX,CR	KL	KL,LX	KL,CR
	RESIDUAL DAMAGES			
Longview	28	28	28	28
Kelso	565	565	565	565
Lexington	59	100	59	100
Castle Rock	183	195	195	183
Unleveed	888	888	888	888
Transportation	67	67	67	67
TOTAL RESIDUAL DAMAGES	1,790	1,843	1,802	1,831
	BENEFITS AND COSTS			
BENEFITS	14,715	14,662	14,703	14,674
COSTS	3,690	3,560	3,660	3,590
NET BENEFITS	11,025	11,102	11,043	11,084
BCR	3.99	4.12	4.02	4.09

TABLE IV-6
AVERAGE ANNUAL BENEFITS AND B/C RATIOS FOR
ONE-STAGE RETENTION STRUCTURE ALTERNATIVES
($000)

SRS Alternative (height of spillway in ft)	Damage Reductions	Dredging Savings	Benefits	Costs	Net Benefits	B/C Ratio
50	4,113	13,080	17,193	11,790	5,403	1.46
100	4,113	13,080	17,193	8,760	8,433	1.96
125 (940 NGVD)	4,113	13,080	17,193	8,150	9,043	2.11
150	4,113	13,080	17,193	8,700	8,493	1.98
200	4,113	13,080	17,193	11,250	5,943	1.53

TABLE IV-7
COSTS, BENEFITS, AND RESIDUAL DAMAGES OF A 125-FOOT (940 NGVD) SRS WITH MINIMAL LEVEE RAISES
($000)

Location	SRS only	SRS with KL,LX,CR	SRS with KL	SRS with KL,LX	SRS with KL,CR
			RESIDUAL DAMAGES		
Longview	124	124	124	124	124
Kelso	10,222	1,699	1,699	1,699	1,699
Lexington	227	151	227	151	227
Castle Rock	234	192	234	234	192
Unleveed	1,488	1,488	1,488	1,488	1,488
Transportation	97	97	97	97	97
TOTAL RESIDUAL DAMAGES	12,392	3,751	3,869	3,793	3,827
			BENEFIT AND COSTS		
BENEFITS	4,113	12,754	12,636	12,712	12,678
BENEFITS, incl. foregone costs1/	17,193	25,834	25,716	25,792	25,758
COSTS	8,150	8,420	8,290	8,390	8,320
NET BENEFITS	9,043	17,414	17,426	17,402	17,438
BCR	2.11	3.07	3.10	3.07	3.10

1/ The cost of base dredging, $13,080,000/year

SRS/Minimum Levee Improvements/Base-Plus Dredging

To this point, the 125 foot spillway SRS with minimal levee improvements at Kelso and Castle Rock, and dredging to maintain base condition channel geometry strategy has shown the greatest net benefits. When an increment of dredging beyond that required for maintenance of the base condition is added to this SRS/levee/dredging strategy, minimal levee improvements at Castle Rock no longer produce benefits equivalent to their costs. Therefore, this plan only includes the levee at Kelso. Because this increment of dredging provides substantially increased protection and a consequent increase in benefits, average annual net benefits increase by $924,000. These are reflected in Table IV-8.

TABLE IV-8
COSTS, BENEFITS, AND RESIDUAL DAMAGES OF
A 125 FOOT (940 NGVD) SRS WITH MINIMAL
LEVEE RAISE AT KELSO AND
BASE-PLUS DREDGING
($000)

Location	Residual Damages
Longview	28
Kelso	565
Lexington	100
Castle Rock	195
Unleveed	888
Transportation	67
TOTAL RESIDUAL DAMAGES	1,843
BENEFITS (including foregone costs 1/	27,742
COSTS	9,380
NET BENEFITS	18,362
BCR	2.96

1/ The cost of base dredging, $13,080,000/year.

Multi-Staged Single Retention Structures (MSRS)

The details of costs, benefits, and benefit/cost ratios for the four MSRS scenarios presented in the previous chapter (page III-14 to III-17) are reported in Table IV-9. The last alternative, Scenario IV, shows the greatest net benefits of the MSRS's at $8,743,000 annually. This compares to $9,043,000 for the comparable single stage structure.

The economics of the MSRS with the highest net benefits (IV) are then combined with those of the various levee options and are presented in Table VI-10.

TABLE IV-9
NET BENEFITS AND B/C RATIO OF MSRS ALTERNATIVES
($000)

MSRS Scenario	Damage Reduction	Dredging Savings	Benefits	Costs	Net Benefits	B/C Ratios
I	4,113	13,080	17,193	9,160	8,033	1.88
II	4,113	13,080	17,193	8,980	8,213	1.92
III	4,113	13,080	17,193	8,610	8,583	2.00
IV	4,113	13,080	17,193	8,450	8,743	2.04

Legend:

I = foundation stage only;
II = through stage two of three;
III = three of three; and
IV = two of two.

TABLE IV-10
COSTS, BENEFITS, AND RESIDUAL DAMAGES,
MSRS SPILLWAY HEIGHT 100'→125',
MSRS WITH MINIMAL LEVEE RAISES
($000)

Location	MSRS only	MSRS with KL,LX,CR	MSRS with KL	MSRS with KL,LX	MSRS with KL,CR
			RESIDUAL DAMAGES		
Longview	124	124	124	124	124
Kelso	10,222	1,699	1,699	1,699	1,699
Lexington	227	151	227	151	227
Castle Rock	234	192	234	234	192
Unleveed	1,488	1,488	1,488	1,488	1,488
Transportation	97	97	97	97	97
TOTAL RESIDUAL DAMAGES	12,392	3,751	3,869	3,793	3,827
			BENEFITS AND COSTS		
BENEFITS	4,113	12,754	12,636	12,712	12,678
BENEFITS, incl. foregone costs[1/]	17,193	25,834	25,716	25,792	25,758
COSTS	8,450	8,720	8,590	8,690	8,620
NET BENEFITS	8,743	17,114	17,126	17,102	17,138
BCR	2.04	2.96	2.99	2.97	2.99

1/ The cost of base dredging, $13,080,000/year.

As shown on Tables IV-6 and IV-9, annual net benefits for the SRS with a 125-foot spillway are greater than for a MSRS with foundation at 100-feet and 25-feet additional for a 125-foot spillway ($9,043,000 and $8,743,000, respectively). Adding minimal levees at Kelso and Castle Rock to the SRS and MSRS (with base condition dredging in outyears) described above increases annual net benefits to $17,438,000 and $17,138,000, respectively. While not shown in a specific table, it should be noted that, if the second MSRS stage construction is completed 11 years after the foundation, average annual costs are the same for both the SRS and MSRS. This is because of the discounted value of the delayed cost for the second stage.

THE NATIONAL ECONOMIC DEVELOPMENT PLAN ASSUMING 550 MCY FORECAST

The best dredging only alternative, intermediate dredging, has net average annual benefits of $7,912,000. The minimal levee raises at Kelso, Lexington, and Castle Rock have $12,041,000 in net benefits. The SRS with base-plus dredging in outyears and a minimum levee raise at Kelso has average annual net benefits of $18,362,000. The MSRS (initial height 100-feet, raised to 125 feet in 1996) with minimal levee raises at Kelso and base-plus dredging provides net benefits of $18,062,000 annually. Table IV-11 provides a comparison of minimal levee raises, the best SRS and MSRS options, and the intermediate dredging option against base dredging. Table IV-12 presents the plans against no action. All comparisons show the NED plan is the 125-foot SRS, with minimal levee improvement at Kelso, and base-plus initial and outyear dredging alternative. Tables IV-13, 14, and 15 display total project costs for the best dredging, SRS and MSRS alternatives.

TABLE IV-11
COMPARISON OF DREDGING, SRS AND MSRS PLANS
(Average Annual $000)

Location	Base w/Min Levees KL,LX,CR 1/	SRS w/Min. Levees KL, CR (Base)	Inter. Dr. w/Min. Levee KL	SRS w/Min. Levees KL (Base-Plus)	MSRS w/Min. Levees KL (Base-Plus)
		RESIDUAL DAMAGES			
Longview	180	124	28	28	28
Kelso	1,846	1,699	565	565	565
Lexington	165	227	100	100	100
Castle Rock	282	192	195	195	195
Unleveed	1,589	1,488	888	888	888
Transportation	132	97	67	67	67
TOTAL RESIDUAL DAMAGES	4,194	3,827	1,843	1,843	1,843
		BENEFITS AND COSTS			
BENEFITS	12,311	12,678	14,662	14,662	14,662
BENEFITS, incl. foregone costs 2/	25,391	25,758	27,742	27,742	27,742
COSTS	13,350	8,320	16,640	9,380	9,680
NET BENEFITS	12,041	17,438	11,102	18,362	18,062
BCR	1.90	3.10	1.67	2.96	2.87

1/ Increment for levee raises only. Base dredging costs are assumed and not calculated in costs or benefits.

2/ The cost of base dredging, $13,080,000/year

TABLE IV-12
COMPARISON OF DREDGING, SRS AND MSRS PLANS TO NO ACTION
(Average Annual $000)

Location	Base w/Min Levees KL, LX,CR 1/	SRS w/Min. Levees, LK, CR (Base)	Inter. Dr. w/Min. Levee KL 3/	SRS w/Min. Levee KL (Base-Plus)	MSRS w/Min. Levee KL (Base-Plus)
RESIDUAL DAMAGES					
Longview	180	124	28	28	28
	(71 yrs)1/	(100 yrs)	(167 yrs)	(167 yrs)	(167 yrs)
Kelso	1,846	1,699	565	565	565
	(70 yrs)	(77 yrs)	(143 yrs)	(143 yrs)	(143 yrs)
Lexington	165	227	100	100	100
	(125 yrs)	(91 yrs)	(167 yrs)	(167 yrs)	(167 yrs)
Castle Rock	282	192	195	195	195
	(91 yrs)	(91 yrs)	(118 yrs)	(118 yrs)	(118 yrs)
Unleveed	1,589	1,488	888	888	888
Transportation	132	97	67	67	67
TOTAL RESIDUAL DAMAGES	4,194	3,827	1,843	1,843	1,843
BENEFITS AND COSTS					
BENEFITS2/	39,217	39,584	41,568	41,568	41,568
COSTS	13,350	8,320	16,640	9,380	9,680
NET BENEFITS	25,867	31,264	24,928	32,188	31,888
BCR	2.94	4.76	2.50	4.43	4.29

1/ Level of protection provided at safe levee height.

2/ Compared with no action.

TABLE IV-13

DREDGING-BASE CONDITION AND KL/LX/CR MINIMUM LEVEES

TOTAL PROJECT COST

($ millions)

<u>Total Project Cost</u>

Dredging		276.29
Construction	244.47	
Real Estate	9.15	
Mitigation	22.67	
Levees		5.46
Construction	1.48	
Real Estate	2.06	
O&M	1.92	
Other		70.35
Disposal Site Rahab.	10.20	
Revetments	9.35	
D/S Monitoring	50.80	
	TOTAL PROJECT COST	352.10

TABLE IV-14

125-FOOT SRS WITH COWLITZ BASE-PLUS DREDGING AND KL MINIMUM LEVEE

TOTAL PROJECT COST

($ millions)

<u>Total Project Cost</u>

SRS		98.9
Construction	63.7	
O&M	16.1	
Monitoring	5.2	
Real Estate	12.2	
Relocation	0.4	
Mitigation	1.3	
Dredging		84.8
Construction	76.15	
Real Estate	4.32	
Mitigation	4.33	
Levee (KL Min. Levee)		2.8
Cost	0.74	
Real Estate	1.10	
O&M	0.96	
Other		44.6
Revetment	0.00	
Disposal Site Rehab.	6.80	
D/S Monitoring	37.80	
	TOTAL PROJECT COST	231.1

TABLE IV-15

MSRS 100-FOOT TO 125-FOOT WITH COWLITZ DREDGING AND KL MIN LEVEE

TOTAL PROJECT COST

($ millions)

Total Project Cost		
Staged SRS		99.9
Construction	64.6	
O&M	16.1	
Monitoring	5.2	
Real Estate	12.2	
Relocation	0.4	
Mitigation	1.3	
Dredging		89.7
Construction	80.8	
Real Estate	4.4	
Mitigation	4.5	
Levee (KL Min. Raise)		2.8
Cost	0.74	
Real Estate	1.10	
O&M	0.96	
Other		43.7
Revetment	0.00	
Disposal Site Rehab.	7.90	
D/S Monitoring	35.80	
	TOTAL PROJECT COST	236.1

SENSITIVITY OF THE NED PLAN TO SEDIMENT DELIVERY

Because of the dynamic nature of the sediment budget in the Toutle/Cowlitz system, the NED plan was analyzed for sensitivity to increases and decreases in the forecast during the 50-year planning period. Its net benefits were considered if the sediment yield is at the predicted 550 mcy estimate level (E), one-half of the expected number (1/2 E), and one and one-half of the expected number (1-1/2 E), . The conditions that must be accepted in order to expect an E, 1/2 E or 1-1/2 E are discussed in the following section.

Sediment Yield Premises

Premise Set One: If the positions are held that:

1) Volcanic and mudflow activity will remain constant at levels observed since the 1980 eruption.

2) There will be no major lake breakouts.

3) Mudflows will keep stream channels unstable.

4) Large storms will cause major disruptions of the stream channels, cut them deeply, and erode avalanche deposits.

5) Channel incision will exceed 12 feet.

6) Downstream from Coldwater, North Fork Toutle will continue to meander and erode all deposits above the existing stream profile.

7) Only tributary streams will armor during the project life.

8) Natural recovery will not significantly affect erosion.

9) Consultants' recommendations are sound.

10) The 550 mcy of erosion of well-graded material from the debris avalanche would deposit as 640 mcy of poorly-graded material.

Conclusion Set One: The sediment budget expected over the 50-year ~~period~~ is 550 mcy ("E").

Premise Set Two: If the positions are held that:

All premises will be the same as Set One, except:

Volcanic activity will be significantly less than predicted levels, reducing mudflow yields and allowing more channel stability.

OR

All premises will be the same as set one except:

Stream channels will be more stable and large storms will not cause major disruption of the channels.

Conclusion Set Two: The sediment budget expected over the 50-year period would be approximately 1/2 E.

Premise Set Three: If the positions are held that:

All premises will be the same as set one, except:

Volcanic activity will be significantly higher than predicted levels, causing frequent large mudflows.

OR

All premises will be the same as set one, except:

Downstream from Coldwater, North Fork Toutle will erode down to the pre-eruption profile.

Conclusion Set Three: The sediment budget that would be expected over the 50-year period would be approximately 1-1/2 E.

For purposes of this sensitivity analysis, aggregate costs to society include the cost for a measure and the residual damages it allows. Possible measures are compared according to these costs. Three measures are considered here: (1) the SRS, base-plus dredging and levee improvements which comprise the NED, i.e., an embankment structure with a 125-foot spillway and minimal levee improvement at Kelso; (2) base dredging with minimal levee raises at Kelso, Lexington and Castle Rock (this dredging and levee measure was selected for comparison because it has the greatest net benefits among the dredging/levee options); and (3) intermediate dredging with minimal levee improvement at Kelso. This alternative is presented here for purposes of comparison. Although this plan has fewer net benefits than the base dredging-levee plan, it reduces residual flood damages to those equivalent to the SRS alternative.

Table IV-16 reflects the relative societal costs for these options under E, 1-1/2 E, and 1/2 E. The SRS with levees continues to register the least cost under E and 1-1/2 E conditions. However, if 1/2 E proves to pertain in the future, the dredging and levee measures have a lower cost.

TABLE IV-16
AVERAGE ANNUAL COSTS TO SOCIETY OF SELECTED MEASURES WITH
E, 1/2 E, AND 1-1/2 E SEDIMENTATION
($M)

	E	1/2 E	1-1/2 E
SRS with 125-foot Spillway with D/S Base-Plus Dredging and Minimal Levee Raise at KL	11.22	9.73	14.91
Base Dredging With Minimal Levee Raise at KL, LX and CR	17.54	8.02	23.95
Intermediate Dredging with Minimal Levee Raise at Kelso	18.48	6.98	28.63

Figure IV-1 shows the best SRS design for each budget; 100' - 1/2 E budget; 125' - E; 150' - 1-1/2 E. Figures IV-2, IV-3 and IV-4 consider the 100-, 125-, and 150-foot spillway SRS's compared to the base dredging alternative and to intermediate dredging, for 1/2 E, E and 1-1/2 E. Figure IV-2 shows that the NED SRS alternative (125-foot) is the least costly when the sediment budget exceeds 0.64 E. All alternatives in these figures contain levee improvements described in Table IV-16.

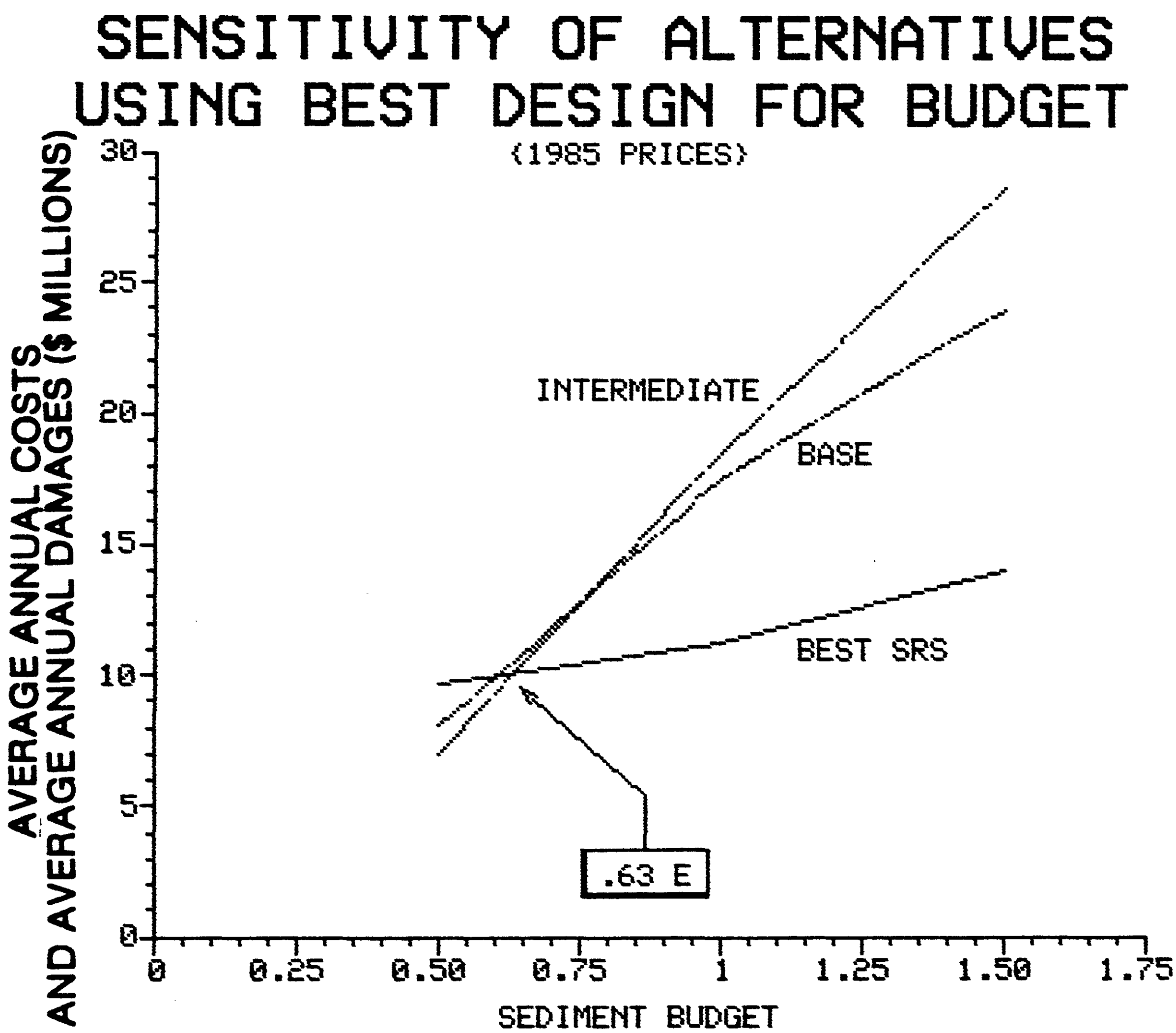


FIGURE IV-1: SENSITIVITY OF ALTERNATIVES USING BEST DESIGN FOR BUDGET (E) (1985 PRICES)

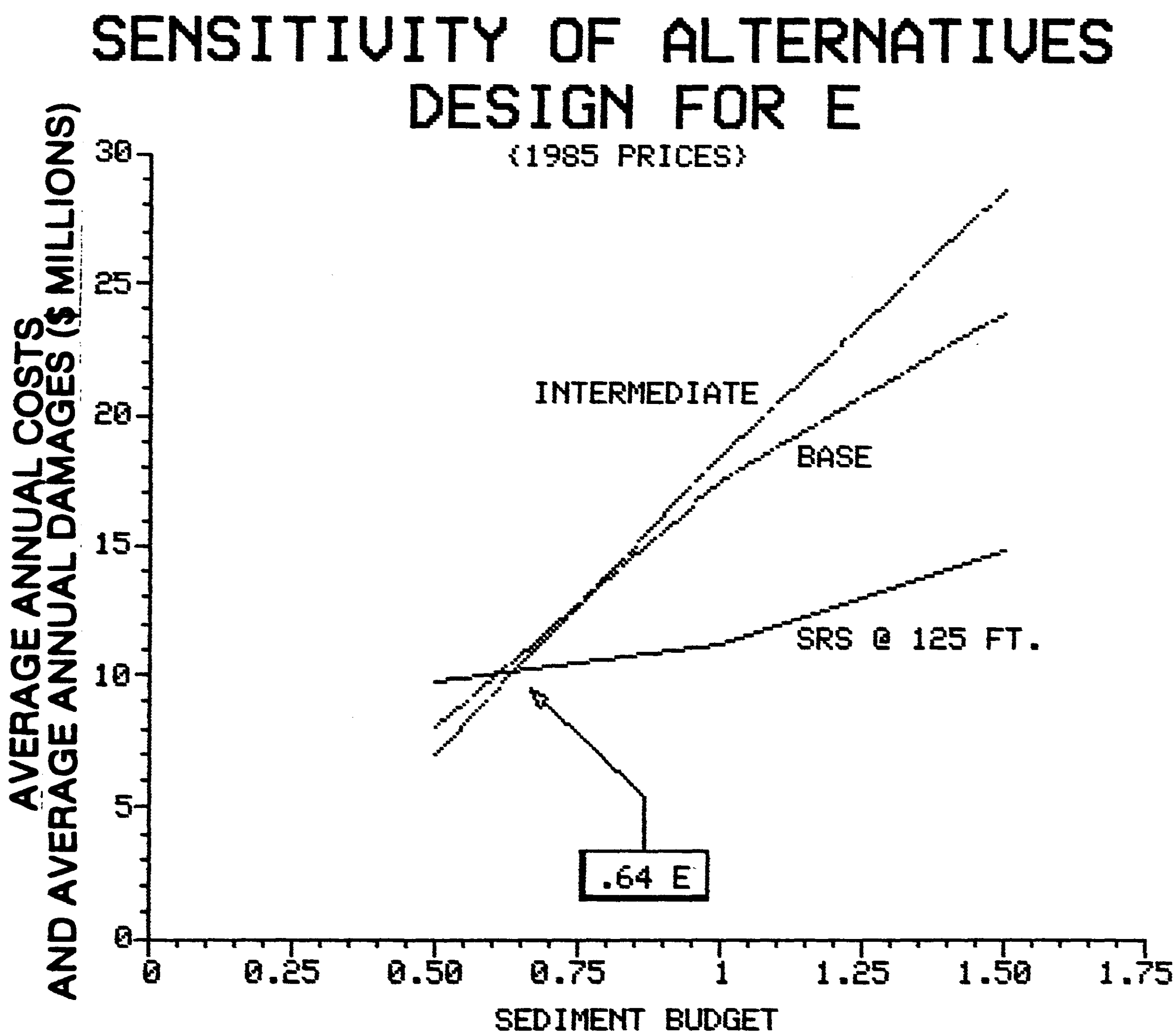


FIGURE IV-2: SENSITIVITY OF ALTERNATIVES DESIGN FOR E
(1985 PRICES)

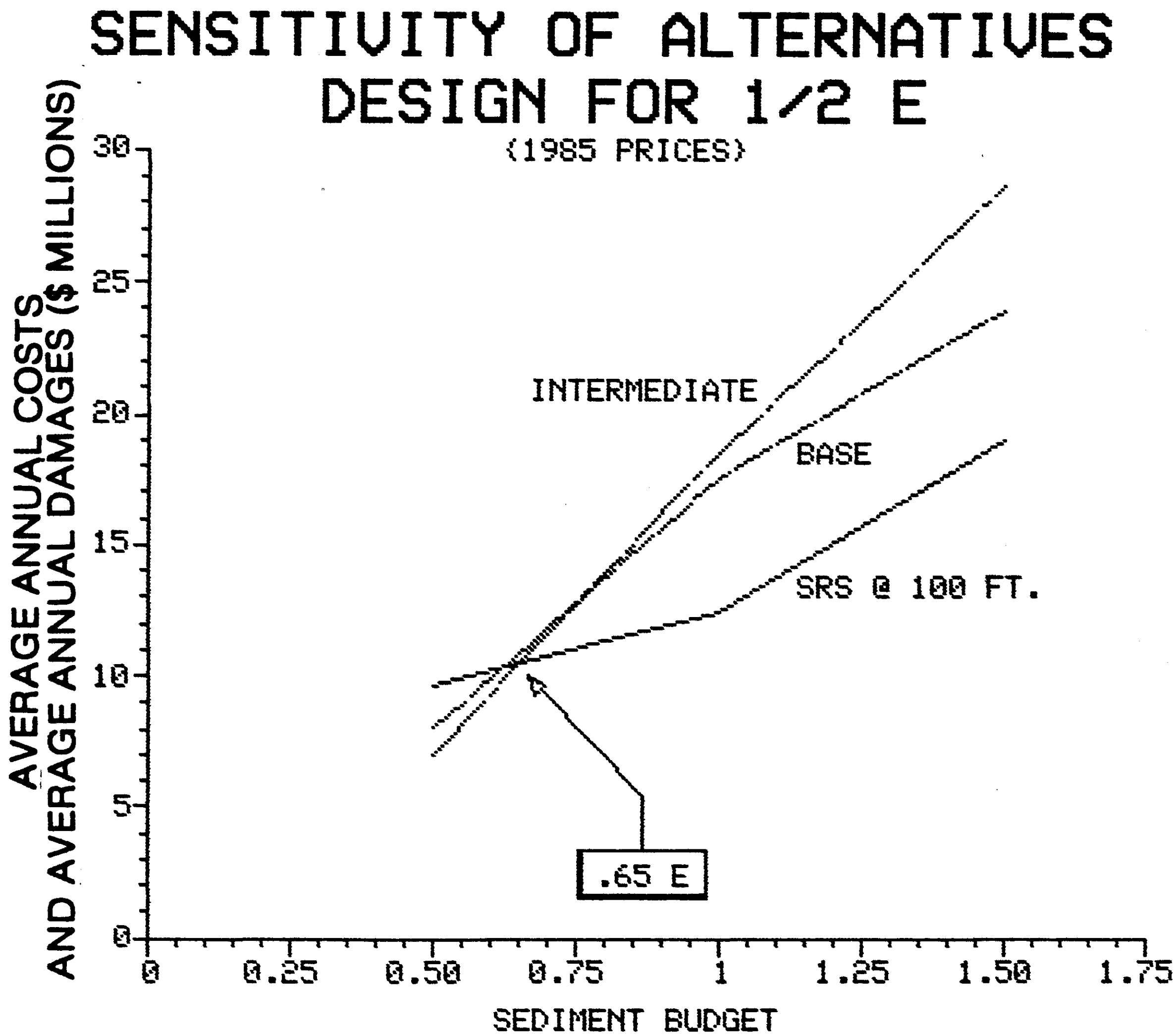


FIGURE IV-3: SENSITIVITY OF ALTERNATIVES DESIGN FOR 1/2 E
(1985 PRICES)

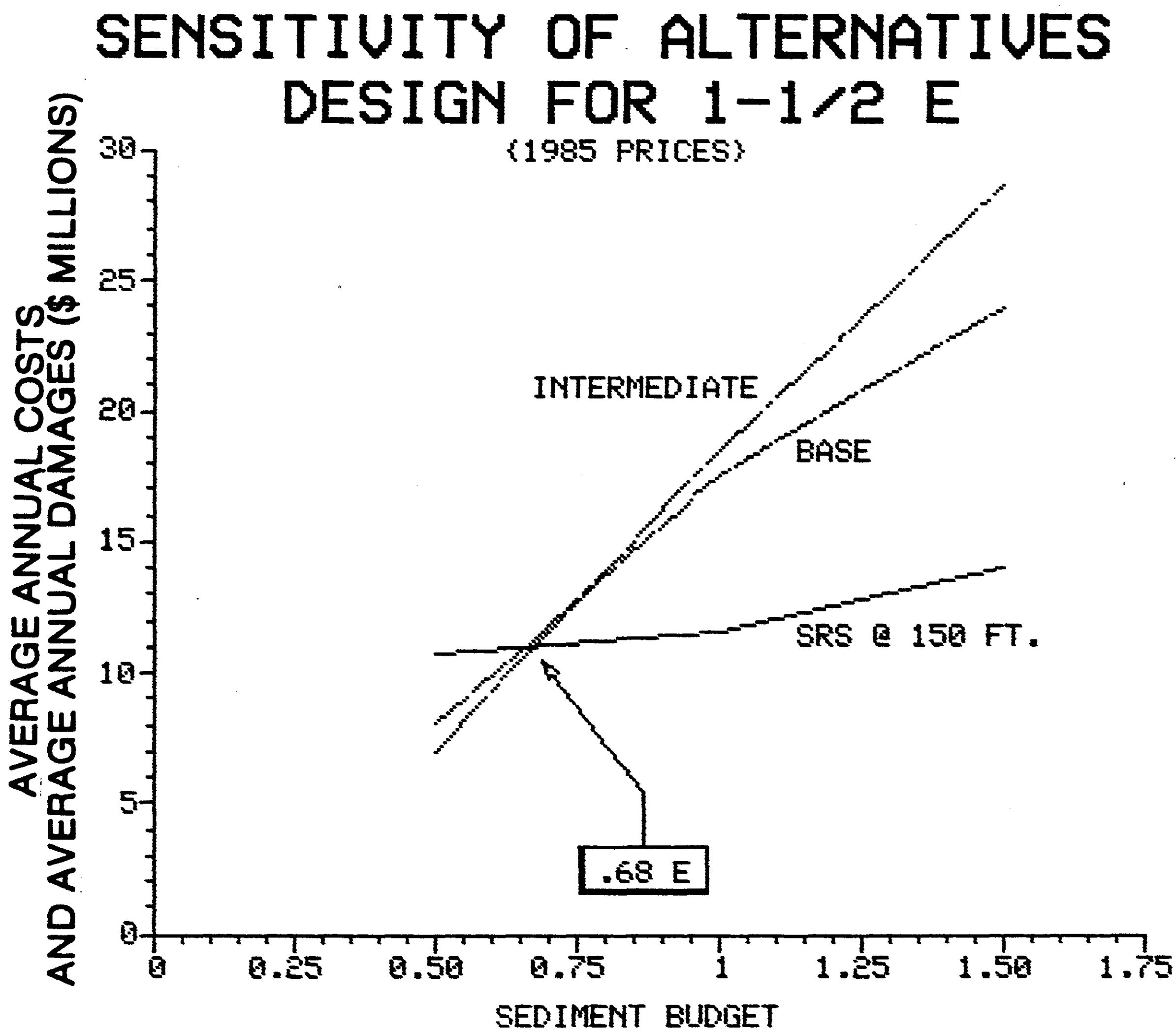


FIGURE IV-4: SENSITIVITY OF ALTERNATIVES DESIGN FOR 1-1/2 E (1985 PRICES)

CHAPTER V

ENVIRONMENTAL EVALUATIONS

OF ALTERNATIVES

INTRODUCTION

Relationship to Other Reports

The environmental effects of the single retention structure (SRS) alternatives were described in a Final EIS, which was included with the Mount St. Helens Feasibility Report, completed in December 1984. This EIS was reviewed by other agencies and the public in full procedural compliance with CEQ regulations for implementing NEPA. The Feasibility Report and EIS were accompanied by a U.S. Fish and Wildlife Coordination Act Report, addressing the biological effects of SRS alternatives. For this Decision Document, the U.S. Fish and Wildlife Service (USFWS) has prepared a Continuing Planning Aid Letter, supplementing the findings reported in their earlier Coordination Act Report, and addressing the effects of the dredging and levee raise alternative set.

Scope

To avoid duplication, this chapter summarized the information contained in the reports discussed above. New information is added which addresses the physical, social and economic effects of the dredging and levee raise alternatives.

AFFECTED ENVIRONMENT

Physical Environment

The North Fork Toutle River has its origins on the northwest slopes of Mount St. Helens. Its upper valley contains massive amounts of material from the debris avalanche released by the 18 May 1980 eruption. Downstream from the debris avalanche, the North Fork courses through the material deposited by mudflows to its confluence with the South Fork, forming the Toutle River. As the gradient of the stream bed decreases in the lower valley, sedimentation increases, causing channel infilling, increased channel widths, and bank

erosion. At the confluence of the Toutle and Cowlitz Rivers, substantial deposition and bank erosion occurs.

Upstream from the Toutle River confluence (RM 20), the Cowlitz is relatively clean; below the confluence, the Cowlitz carries the sediment load delivered by the Toutle. Substantial deposition of sediment occurs in the Cowlitz; the mounds of material excavated from the channel and placed on the shorelines near Castle Rock are evidence of the sedimentation which has continued since the eruption. Sediment is further transported by the Cowlitz to the Columbia. These rivers are in a state of transition, seeking a new equilibrium following the addition of billions of cubic yards of erodible material into the system by the eruption of Mount St. Helens.

Other streams less affected by the eruption contribute flows to the system. The major tributaries to the Toutle River are the Green River and the South Fork Toutle River. The 18 May blast affected both of them. The blast denuded the upper watersheds of these streams and of the North Fork Toutle River Valley, affecting their hydrologic characteristics. A mudflow caused erosion and deposition throughout the South Fork Toutle River Valley. The Green River watershed was primarily affected by ashfall produced by the blast. These streams are now relatively clean and contribute only small amounts of suspended sediment to the system.

The debris avalanche is 17 miles long and over 600 feet deep in some locations. It averages 150 feet deep, tapers down to 10 feet of depth at the toe, and has an overall slope of about 3 percent. The total estimated volume of the avalanche is about 3.8 billion cubic yards. The material in the avalanche varies in size from silts and clays ("fines"), to sand, gravel, cobbles and boulders.

The fine materials are easily eroded and transported, move downstream suspended in the flow and are carried into the Columbia River. Few fines are expected to remain in the Toutle-Cowlitz River system. Medium and fine sand-size material is the major source of sedimentation. Sand is transported through the steeper gradient reaches of the North Fork and Main Stem Toutle Rivers, but as the river gradient becomes less steep and the flow less rapid,

the sand particles deposit, particularly in the lower 20 miles of the Cowlitz River.

Biological Environment: Fisheries

Prior to the eruption, streams in the Cowlitz-Toutle watershed supported anadromous and resident fish populations. Anadromous fish included wild-run and hatchery-produced fall and spring chinook, coho salmon, winter and summer steelhead trout, and sea-run cutthroat trout. Hatcheries accounted for the majority of the anadromous fish production in the basin containing the Cowlitz and Toutle River drainages.

The eruption of Mount St. Helens significantly affected the fishery of this area, although the degree of impact varied by tributary. The existing condition reflects the dynamic condition of a disturbed environment. The fishery, dependent upon the quality and quantity of available habitat, continues to be affected by ongoing sedimentation, while slowly recovering toward the pre-eruptive condition. The Toutle River fishery resource has recovered in the past after prior eruptions of Mount St. Helens; and it is expected to recover through time to a condition similar to that of the pre-eruption state. Any description of the current condition of this resource must, consequently, be viewed as a temporary condition with improvement underway. By river system, the following conditions exist.

Toutle River

The present condition of fish habitat in the Toutle River system varies greatly, depending upon the degree of impact caused by the eruption and extent of continued perturbation. For example, the eruption did not affect Alder Creek (a tributary to the North Fork Toutle upstream from the Green River), and it currently provides productive habitat. At present, these smaller tributaries, such as Alder Creek, provide the major spawning and rearing habitat available in the upper North Fork Toutle. Eventual major production, however, is more closely related to the habitat provided by the larger streams: the North Fork Toutle, South Fork Toutle, and Green River. As described in greater detail in the sediment appendix, the continuing

sedimentation and erosional processes affect these major tributaries to varying degrees. It is projected that the North Fork Toutle will continue, as is currently the case, to experience major sediment deposition from the debris avalanche. This impact and associated channel destabilization will prevent the reestablishment of productive fisheries habitat for some time. The Green River and South Fork Toutle are not experiencing the habitat-limiting impacts of the North Fork Toutle and are showing signs of recovery. However, the lack of riparian vegetation, which provides shading to cool waters to favorable levels, limits fish production. Currently, high stream temperatures, particularly on the Green River, affect production adversely.

The main stem Toutle River continues to experience the effects of habitat-inhibiting sedimentation. Continuing erosion creates a stream where fish must contend with turbidities higher than any stream in America, if not the world; a stream that continuously shifts course and does not allow the reestablishment of mature riparian vegetation; a stream where sediment continues to bury stream gravels. In whole, it is a stream where the continued existence of an anadromous fish run is a tribute to the survival instinct of the species. Throughout the Toutle River Basin, eruption-related events affected about 135 miles (77 percent) of the streams used by anadromous fish. This included all of the larger streams (about 101 miles) and 34 miles (46 percent) of the accessible tributaries. About 62 miles of resident fish habitat were also harmed.

Besides the problems affecting natural anadromous fish production in the basin, hatchery production which adds substantially to overall production from this basin continues to be lost. Mudflows inundated the Toutle Salmon Hatchery as well as the Deer Creek rearing pond. They are currently inoperable. Since hatcheries produced approximately 70 percent of the salmon and 60 percent of the steelhead in this basin, this loss greatly influences eventual production.

Cowlitz River

The Cowlitz River serves primarily as a migratory pathway for anadromous salmon and trout produced in the Toutle and upper Cowlitz systems, although

some rearing and spawning habitat existed prior to the eruption. A large spawning run of smelt continues to use this river.

The Cowlitz River downstream from the Toutle River remains severely affected by the sediment from the Toutle. Spawning gravels once present are buried under several feet of sediment. The sediment delivery to this river reach persists, creating difficult passage conditions. Above the confluence of the Toutle River, the upper Cowlitz is unchanged from the pre-eruptive condition. Pre-eruption anadromous fish hatchery production of the Cowlitz River approximated three times that of the Toutle River basin. With the severe damage that has occurred in the Toutle system, the upper Cowlitz fish now make up the majority of anadromous fish population in the basin.

Hatcheries in the upper Cowlitz River provide the majority of this production. These hatcheries compensate for fish losses associated with the Tacoma City Light dams on the upper Cowlitz. They produce fish at or near maximum capacity to provide a Cowlitz River fishery.

Columbia River

The Columbia River is critically important to the region's anadromous fish populations. It is the major migratory corridor for the region and provides important rearing habitat. While the Columbia continues receiving sediment, the impact of this sand and silt on the fishery resource is unknown. It is believed, however, that the higher turbidity and shoaling from this additional sediment does adversely affect the fisheries resource.

Biological Environment: Wildlife

Existing vegetation and other factors directly influence the reestablishment of wildlife populations. The eruption resulted in varying impacts to the vegetation, and, hence, wildlife populations. Like the fisheries habitat previously described, the status of wildlife habitat is dynamic; recovery is underway.

Toutle River

The eruption severely affected Toutle River wildlife habitat, although the degree of impact varies considerably by area. Mudflows caused loss of riparian vegetation along the lower reaches of the Toutle, while areas nearer the mountain suffered from blast effects which damaged whole forest communities. Currently, channel meandering continues to impede the establishment of riparian vegetation along much of the drainage. Ongoing sedimentation continues to retard recovery within this floodplain corridor. In areas away from this influence, the recovery of wildlife habitat is occurring quite rapidly.

Cowlitz River

This area previously suffered debasement due to numerous residential and commercial developments along its banks prior to the eruption. Mudflow associated with the eruption further degraded this area and the need for disposal areas during emergency dredging operations also reduced the limited wildlife habitat available. Consequently, Cowlitz River wildlife populations remain low.

Columbia River

The lower Columbia River provides valuable wildlife habitat. The riparian/ wetland communities support abundant avian populations including important migratory and wintering waterfowl.

Social and Economic Setting

Population in the study area is concentrated along the lower Cowlitz River, primarily in the incorporated communities of Kelso (11,000), Longview (30,100), and Castle Rock (2,140) (1983 populations), and the unincorporated community of Lexington. Over fifty percent of the population of Cowlitz County lives in Kelso and Longview, on opposite sides of the Cowlitz River.

Land use in Longview consists of valuable high density residential and commercial development within the city limits, with large areas of industrial activity located in the leveed flood plain of the Cowlitz and Columbia Rivers. In Kelso, single family residential is the largest land use, with a small amount of land in commercial use. Castle Rock and Lexington land use is mainly residential; the remaining rural floodplain provides areas for agriculture, dredged material disposal, and for a minor amount of industrial activity.

The Cowlitz Valley is a segment of a major transportation corridor. It contains Interstate Freeway 5, the major route for the vehicular traffic between Portland, Oregon, and Seattle, Washington. The Burlington Northern and Union Pacific railroad tracks carry an estimated 22 trains per day, including freight and AMTRAK passenger trains. The rights-of-way for these transportation modes are vulnerable to damage by flooding where their bridges cross the Toutle River near its confluence with the Cowlitz.

The economy of Cowlitz County is based on manufacturing industries, with the lumber, wood products, and paper products industries the most important. Retail trade, services, and government are the next largest sectors of the economy. The Kelso-Longview area is the largest center of industrial activity and employment in the county.

ENVIRONMENTAL EFFECTS

Physical Environment

Sediment Retention Structure

The single sediment retention structure alternative entails constructing a single (SRS) or multiple stage (MSRS) retention structure on the North Fork Toutle River with enough storage to trap most of the material projected to erode from the debris avalanche. Downstream dredging would be necessary to remove material to achieve the desired Cowlitz channel condition below the site and to remove sediment which passes downstream during SRS construction, and between the years 2000 and 2035 after the structure is full. During the

outyears, 27 mcy of material would be removed from and disposed of along the Cowlitz River. Minor levee improvements at Kelso are part of this alternative.

Sediment retained behind the structure will permanently fill in the existing streambed and floodplain of the North Fork Toutle River. High suspended loads and sediment levels and channel instability would continue for prolonged periods in the sediment impoundment area. Once maximum sediment retention is achieved, channel stability could occur across the plateau of impounded sediment.

Impoundment by the sediment retention structure could lead to water quality problems if the project were allowed to store water during the summer and fall. To alleviate potential water quality problems, the multiple-level pipe outlet was designed to pass inflow during normal flows and to minimize storage during storm events, thus minimizing the impoundment retention times of runoff.

Downstream from the structure, dredging in the lower Toutle River could still continue for a year and decrease as channel stabilization and degredation occurred. With the material from the debris avalanche retained in the upper Toutle Valley, physical and biological recovery of the lower river will occur at a greatly increased rate compared to no action conditions. Beyond approximately the year 2000, dredging of 27 mcy of material would take place in the Cowlitz River.

Dredging and Levee Measures

Implementation of the dredging alternative would result in the transformation of the landscape in the Toutle and Cowlitz valleys. Approximately 134 mcy of material would be dredged between 1986 and 2035 to maintain the base channel configuration. Intermediate dredging would raise the total volume to 167 mcy. Of the base dredging total, 92 mcy would come from the Toutle River and 42 mcy from the Cowlitz River. In later project years, dredged material would replace low-lying agricultural land and other open spaces in the Cowlitz Valley. This transformation will occur over a period of fifty years, with

lands adjacent to the Toutle river being filled first, followed by sites adjacent to the Cowlitz. In some areas, the Cowlitz River could flow through a channel formed of dredged material, with sloping walls up to 70 feet high at the site's full development. The filling of sites farther inland would extend this transformation beyond the limits of the river itself.

Dredging activities in the river generally result in increased turbidity. Since existing turbidity levels are already high as a result of the continuous sediment load being carried from the Toutle, this impact would be minimal. Return waters from disposal areas generally will carry high levels of suspended solids unless provisions are made to contain these waters to allow settling before release to the river. Disposal sites farther from the river generally rely on existing drainages to return excess water to the river. Any sediment carried by these return waters usually settle out in these smaller drainages and can adversely affect their ability to drain the inland areas. Erosion over time from the disposal piles might also deposit material in inland drainages impeding natural flows and possibly cause minor flooding.

Each disposal site will be evaluated, prior to its use, to determine the existing drainage requirements in the area and the measures needed to maintain that drainage. If this question is consistently addressed in each case over the project life, no significant problems with drainage and runoff should occur.

Levee raises require extending the bases of some portions of the levees to establish the required safe heights and side slopes. Filling on the inland side of the levees is implied. The amounts of fill required vary depending on the level of protection provided, with the least amount of fill required for the base level and the maximum amount for the 500-year level.

Biological Environment: Fisheries

Single Retention Structure

Toutle River: The construction of a single retention structure at the Green River location will have the following major impacts on the Toutle River fisheries resource:

1. Blockage of natural fish movement
2. Inundation of spawning and rearing habitat, and
3. Downstream impacts.

A structure of this nature would totally block all natural upstream and downstream migration of anadromous fish. Fish passage facilities are proposed. Providing these facilities would allow the continuing reestablishment of anadromous fish runs into tributaries above the SRS.

The backup of sediment behind the structure will inundate the streambed of the North Fork Toutle with sediment. This inundation would not be significant since this stream is already subjected to sedimentation from the debris avalanche. However, the height of sediment backup will also affect tributaries that were not significantly affected by the eruption. Alder Creek, which currently provides productive spawning and rearing areas, will be inundated.

The blockage of downstream sediment movement by this structure will result in more rapid recovery of fish habitat below the structure; improved conditions will develop on approximately 17 miles of main stem Toutle River and 13.2 miles of North Fork Toutle River. With reduced sediment delivery, materials in the stream below the structure will erode and allow the reestablishment of a gravel-bottomed stream with riparian vegetation supporting fishlife. This forecast of downstream recovery depends upon the quality of water released from the impoundment. The potential exists for impounded water to warm to such an extent that when released, its temperature would be detrimental to fish survival. However, with the minimum water impoundment proposed, it is anticipated that outflow water temperatures will not be significantly different than inflow temperatures. Initial downstream and outyear Cowlitz River dredging is proposed as part of this plan. This operation would, however, be greatly reduced under the SRS alternative.

<u>Cowlitz River</u>: The major factor affecting fish habitat in the Cowlitz River is the continuing sedimentation. This alternative, by reducing the amount of material delivered to the Cowlitz, would result in accelerated recovery for this stream from its mouth to the confluence with the Toutle, approximately 20 miles of stream.

Columbia River: Since no significant sedimentation is expected for the Columbia from blast debris with the most recent forecast, no alternative impacts this river's fish habitat.

Dredging and Levee Measures

Dredging operations in the lower Cowlitz River would have little adverse effect on migratory fish. Higher turbidity levels would occur during dredging, temporarily degrading the already poor water quality conditions in the locality of the dredging operation. The magnitude of the increase in turbidity over existing conditions would not be great, and would not be expected to prevent or impede fish migrations. Timing of the dredging work would be coordinated with state and Federal fisheries agencies to minimize adverse effects on migrating fish. However, dredging the sediment deposition from a low probability event occurring immediately to or during a fish run would have potentially significant adverse effects. Dredging operations would be conducted to provide sufficient channel width and depth for fish passage at all times.

Dredging in the lower Toutle River has a greater potential to adversely affect fish passage. Its shallow channels and lesser stream flows could mean almost constant perturbation of fish movements. An adequate fish passage channel can be provided, however, by diverting the channel away from the excavation area and maintaining minimum depths as prescribed by fishery agencies. Dredging in the lower Toutle has occurred during several winters at LT-1 without seriously affecting fish passage.

Biological Environment: Wildlife

Single Retention Structure

Toutle River: The major effect upon wildlife of this measure is the sediment inundation of wildlife habitat behind a single structure. The Green River site inundation area of 3,267 acres is shown in Figure V-1. The major change would occur in types other than barren or disturbed revegetated; these two types, which comprise approximately half the area that would be inundated,

will experience continued perturbation from sedimentation with or without the project. Once the fill of sediment behind the structure subsides, the area is expected to return to a marsh/riparian habitat. Downstream from the structure, the reduction in sediment would allow the recovery of riparian habitat unaffected by continuous channel change. This area, including the area in the Toutle River flood plain inundated yearly, is approximately 1,770 acres.

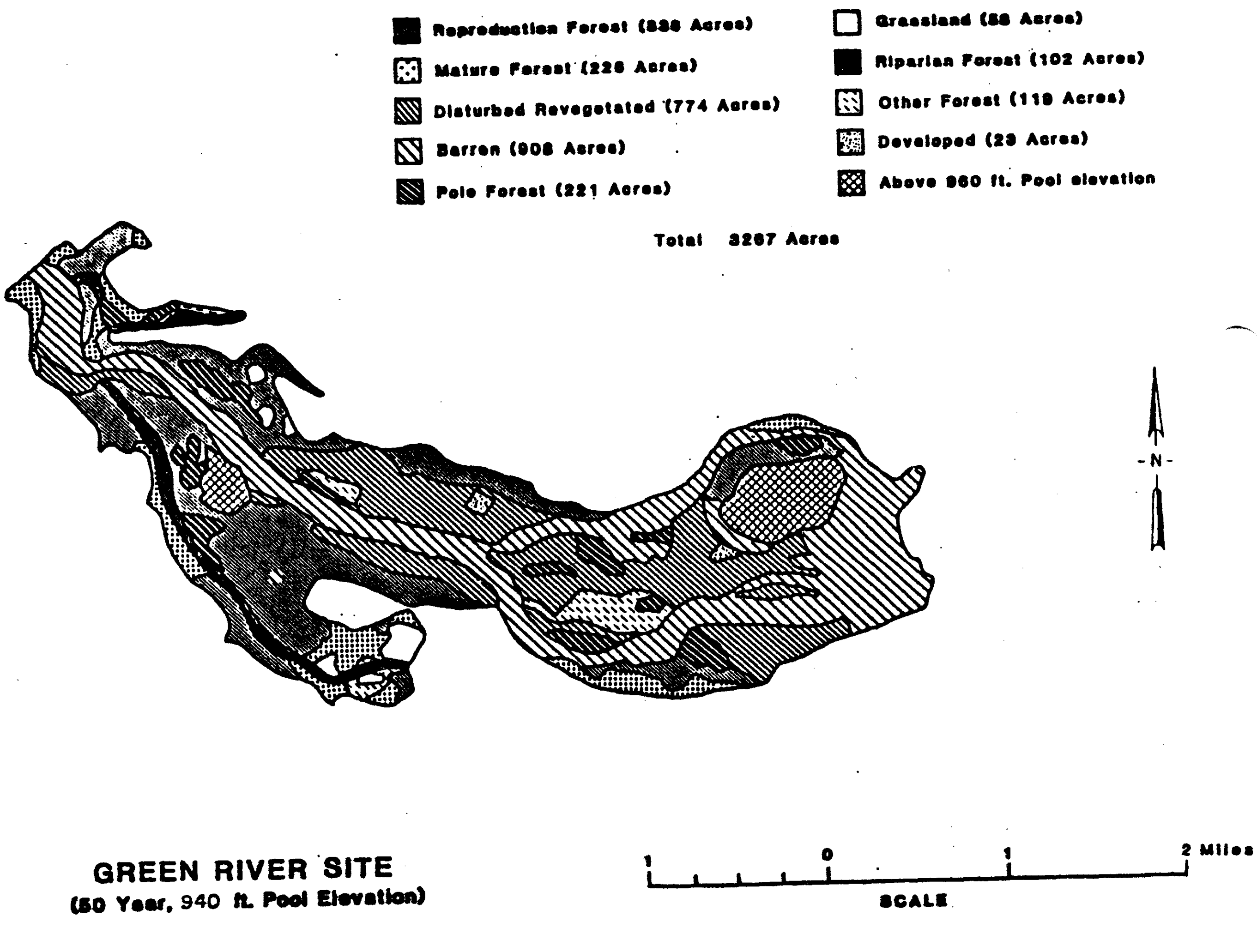


FIGURE V-1. INUNDATION AREA OF GREEN RIVER SITE

Cowlitz River: The reduction of sediment infill and dredging will be beneficial to Cowlitz River wildlife. The reduction in sediment delivery would allow the Cowlitz channel to stabilize and riparian habitat would reestablish sooner than if no action were taken. A reduction in dredging also reduces the amount of wildlife habitat affected by dredged material disposal. In outyears, approximately 32 mcy would be taken from the Cowlitz River with either a SRS or MSRS.

Columbia River: Again with no sediment, no impacts on wildlife habitat can be attributed to the SRS or a MSRS.

Dredging and Levee Measures

This alternative could result in potentially significant adverse effects on wildlife. Further detailed study would be required to assess those effects.

In a preliminary analysis, potential disposal sites on the lower Toutle, Cowlitz and Columbia Rivers were grouped into habitat categories. Acreages of habitat types at each site were identified using a geographic information system analysis of aerial photography. The habitat categories are described in the U.S. Fish and Wildlife Continued Planning Aid letter (see Appendix D), and are used as a basis for estimating mitigation costs and requirements.

The categories, types of habitat, and acreages of each are listed below.

Category 1:	sites which have been previously used for dredged material disposal or urban uses - 3,564 acres.
Category 2:	sites classified as grasslands, shrublands, or agriculture - 1,520 acres
Category 3:	sites classified as wetlands, forests, or open water - 1,694 acres.

These figures represent the maximum amounts of these habitat categories which could be affected by disposal of dredging material. It is likely that some of

the disposal sites identified in this preliminary analysis would not be available for disposal for one reason or another.

For this analysis, a preliminary estimate of mitigation associated with the dredging alternative was derived. Category 1 sites used for dredged material disposal would not require the acquisition of any lands for mitigation, but will require revegetation. Category 2 sites used would require the acquisition of one acre for each acre of disposal, and revegetation of the disposal and mitigation lands. Category 3 sites would require the acquisition of one and a half acres of mitigation land for each acre of disposal and include extensive habitat improvements. Total mitigation land acquisition with the dredging alternative is 4,061 acres.

Losses of wildlife habitat would occur incrementally over the 50-year project life. Sites closest to the rivers would be filled first. Once these are filled to capacity, more distant sites would be used.

The effects of levee raises on wildlife habitat would be relatively minor. The existing levees are in urban areas with minimal wildlife habitat values adjacent to the levees.

Social and Economic Effects

Single Retention Structure

The flood protection provided by this alternative would help to restore favorable conditions in downstream communities, allowing business and commercial activities to proceed as normal business factors permit. Some jobs would be generated by construction of this alternative.

A SRS on the North Fork Toutle River would inundate several private residences, a state highway, a county road, and utilities. Nine homes or buildings would require removal. Downstream dredging would require use of agricultural and other lands for disposal.

Dredging and Levee Measures

Materials from the dredging alternative would eventually fill most of the low lying areas along the Cowlitz River. Sites close to the river and closest to the reaches in which dredging occurs would be the most desirable from the standpoint of engineering and economics. Many sites adjacent to the river are currently used for disposal and would continue to be used until filled to capacity. Utilizing these sites has the least social and economic effects.

Many other sites, further from the river, were never used for disposal and continue to be used for other purposes, such as agriculture or recreation. Disposal of material on these sites would have a much greater impact. These lands would be removed from agricultural production, potentially eliminating a number of economically viable family farming operations in this area. Other sites which are currently used for recreation would not be available for this purpose once disposal begins. Several of these sites are developed parks; their elimination would result in a substantial loss to the communities in which they are located. The most notable example is Riverside Park in the unincorporated community of Lexington.

Several potential sites are adjacent to schools and are being used. Disposal on these sites would curtail these uses while disposal is occurring, leaving these schools adjacent to disposal piles. The elevation of these areas could be up to 70 feet higher after filling than the ground elevation of the adjacent school buildings. Use of these sites for disposal of sediment would have high human impact.

A number of sites contain public works which will need to be relocated, disrupting the sense of community in these areas and the lives of the individuals forced to move.

Evaluation of the social and economic effects of disposal of dredged material at over 100 sites identified in the Cowlitz Valley is complicated by the 50-year life of the project. Locations identified as disposal sites for this action may not be needed for many years. With these sites essentially committed for use as disposal sites at some future time, options available to

the landowner for use or sale of them are restricted. Assuming that rights of entry, easements, or sales would not occur until the need arose for use of the site for disposal, the landowner would probably be reluctant to invest in improvements to the land or the construction or improvement of structures on the site. Although the owner may wish to sell the site to a private party in the interim, it may be hard to find buyers who would be willing to invest in property identified by the Federal government as a potential dredged material disposal site. If sales occur, prices are likely to be affected by this restriction.

The effects of disposal are cumulative over the 50-year project life. Sites closest to the river would be filled first, creating a channel along the lower twenty miles of the Cowlitz River, with sloping walls up to seventy feet high. As sites farther from the river are used, remaining open spaces will be covered with mounds of sandy materials. In some areas, where open space now predominates, existing roads might pass through valleys of dredged material. These effects are most probable in the Lexington area, which is characterized by clusters of residences surrounded by agricultural lands.

Once filling is completed, the ultimate use of the disposal sites could be much different than that which exists today or which might otherwise be planned through zoning regulations or comprehensive plans. What will occur is difficult to predict because of the time span involved and the actual height to which any given site might be filled. Sites filled up to the maximum height of 70 feet may not be suitable for agricultural, residential or industrial development.

Levee raises in Kelso, Longview, Castle Rock and Lexington could require the removal of existing residences on or near the levees. The number of relocations required varies with the level of protection provided by the levee raise. Accomplishment of 100-year level protection requires relatively few removals and relocations, while modifying the levees to provide a 500-year level of protection demands extensive relocations and modifications to existing structures, including the Allen Street Bridge between Kelso and Longview.

SUMMARY

Table V-1 compares the environmental effects of the SRS and DLR measures. Any option principally involving dredging has potentially severe negative impacts on the physical, wildlife, social and economic environments. The SRS calls for more mitigation of impacts on fish runs in the upper Toutle Valley, in the form of programs to insure passage up- and downstream of the structure, but accelerates the full recovery of the Toutle River below the dam and the lower Cowlitz River. Additional staging in outyears might avoid dredging and the associated environmental effects. In aggregate, the SRS or a MSRS is the preferred alternative based on environmental effects.

TABLE V-1

COMPARATIVE ENVIRONMENTAL EFFECTS OF SRS AND DREDGING/LEVEE RAISE ALTERNATIVES

	SRS	DREDGING/LEVEE RAISE
PHYSICAL ENVIRONMENT	Material eroded from debris avalanche would be retained in the Toutle Valley. Material would continue to be carried from sources downstream of the structure for 1 year, but less sediment would be transported to the lower Toutle, Cowlitz and Columbia Rivers than if no structure built. An increase in temperature could occur (in excess of 28°C during the summer months or up to 7-9°F above natural during the remainder of the year) due to ponding behind the SRS. Cowlitz River is dredged for 27 mcy between 2000-2035.	Materials would be transported to the lower Toutle, Cowlitz, and Columbia Rivers. Hills of dredged material would replace low-lying agricultural lands and other open spaces. Increased turbidity due to dredging operations. Return waters from disposal areas could carry sediment which could settle in and fill existing upland drainages, causing minor flooding in small waterways. Levee raise would require extending bases of some levees to establish required height and side slopes; fill would vary depending on level of flood protection provided. Toutle and Cowlitz Rivers dredged for 134 mcy total.
BIOLOGICAL ENVIRONMENT: FISHERIES	Fish passage in the Toutle River would be blocked above the structure. Loss of habitat with sedimentation upstream of the structure. Recovery of downstream channel and habitat would be	Dredging in the lower Cowlitz would have little adverse effects on migratory fish, assuming operations could be scheduled to avoid major fish runs. This would be particularly problematical if a low

	SRS	DREDGING/LEVEE RAISE
	accelerated as sedimentation and suspended solids are reduced in lower Toutle, Cowlitz and Columbia Rivers. There would be outyear dredging impacts to a lesser degree only.	probability flood occurred immediately before or during a fish run. Dredging in the lower Toutle would have greater potential to adversely affect fish passage; however, care would be taken to provide an adequate fish passage channel separated from the excavation area. Levee raise would not adversely affect fisheries or wildlife.
BIOLOGICAL ENVIRONMENT: WILDLIFE	Establishment of vegetation upstream of the structure would be delayed until erosion of debris avalanche stabilizes. Riparian habitat in the lower Cowlitz would recover more rapidly than if no structure were built. Less land would be needed for dredged material disposal than under a principally dredging option.	Potentially significant adverse effects to wildlife could result from the disposal of dredged material on as many as 6,778 acres on the lower Toutle, Cowlitz and Columbia Rivers. Habitat values at these sites range from low-value disturbed areas to wetlands, forest, or open water. Habitat losses would occur incrementally over the 50-year project life. Further detailed study would be required to assess the effects of dredging on wildlife. The effects of levee raises would be relatively minor.
SOCIAL AND ECONOMIC EFFECTS	Beneficial effects to community viability and economic stability in	Most of the low-lying areas along the lower Cowlitz River could eventually be filled,

SRS	DREDGING/LEVEE RAISE
downstream communities as flood protection is restored and sediment is retained in upper Toutle Valley. Relocation of residencies upstream of the structure would be required.	including sites currently being used for recreation,agriculture, school athletics, residences and businesses. Over 100 sites in the lower Cowlitz Valley have been identified for use as areas for the 50-year project life. Businesses and residences would be relocated, disrupting the sense of community. Open spaces would be replaced by hills of material up to 70-feet high, which may not be suitable for any kind of future industrial or residential development.

STATUS OF COMPLIANCE OF ALTERNATIVES WITH ENVIRONMENTAL LAWS, REGULATIONS, AND EXECUTIVE ORDERS

National Environmental Policy Act

1. SRS: A Draft and Final EIS were prepared in compliance with this Act, and were circulated for public and agency review and comment. The Final EIS was sent forward by the Chief of Engineers to the Secretary of the Army as part of the Feasibility Report.

2. Dredging and Levee Raise (DLR): If this alternative is selected, a supplement to the Feasibility Report EIS will be required.

Clean Water Act

1. SRS: A water quality evaluation, as required by Section 404(b)(1) of the Act, was prepared and signed by the District Engineer following public

review and comment. This evaluation was included in the Feasibility Report and FEIS sent forward by the Chief of Engineers. Compliance with the Clean Water Act will be accomplished through the provisions of Section 404(r) of the Act.

2. DLR: Section 404 evaluations will be completed as required before disposal occurs at individual sites. State water quality certification will be required.

Coastal Zone Management Act of 1973, As Amended

No action under either of these alternatives would occur within the coastal zones of Washington or Oregon. This Act is not applicable.

Endangered Species Act of 1973, As Amended

1. SRS: The U.S. Fish and Wildlife Service was consulted and a determination was made that no threatened or endangered species would be adversely affected.

2. DLR: Consultation with USFWS would be required for each of the proposed disposal sites.

Fish and Wildlife Coordination Act

1. SRS: The USFWS was consulted in compliance with this Act. A Coordination Act Report, coordinated with other Federal and State resource agencies, was received.

2. DLR: The USFWS was consulted in compliance with this Act. A draft Continuing Planning Aid Letter was received and is included in this Decision Document (see Appendix D).

Marine Protection, Research and Sanctuaries Act of 1972, As Amended

1. SRS: Not applicable.

2. DLR: If dredging needs exceed the availability of disposal sites along the lower Cowlitz and Toutle Rivers, transport of dredged material to

the ocean may be considered. A Section 105 evaluation would be required before ocean disposal could occur.

Preservation of Historical Archeological Data Act of 1974 and National Historic Preservation Act

1. SRS: Full compliance. A cultural resources investigation was completed and concurrence with the findings received from the State Historic Preservation Officer. No adverse effects to cultural resources are anticipated with this alternative.

2. DLR: Cultural resources investigations for most of the proposed disposal sites would be required. Some sites which were used previously have received cultural resources clearances.

Executive Order 11988, Floodplain Management

Implementation of any of the measures except the no-action strategy would help to stabilize hydraulic conditions in the Cowlitz and Toutle Rivers and allow local authorities to develop plans to manage future use of the flood plains. Floodplain lands would be reduced by any of the options including dredging.

Executive Order 11990, Protection of Wetlands

1. SRS: The effects of the SRS on wetlands are discussed in the Feasibility Report EIS, and the Continuing Planning Aid letter (Appendix D). Outyear dredging impacts are much lower than those under DLR.

2. DLR: The effects of dredging on wetlands are discussed in the Continuing Planning Aid Letter which is contained in this Decision Document. Further analysis and discussion would be required in a supplement to the Feasibility Report EIS.

CHAPTER VI - CONSIDERATIONS FOR DECISION MAKING

DISCUSSION

Background for the Decision Document

The current CP&E studies include an analysis of four alternative measures (dredging, SRS, MSRS, and levees) to an equal level of detail. Typically, fewer measures would be addressed during this study phase. The uniqueness of existing conditions in the Cowlitz/Toutle River basin dictates the current approach; specifically, the eruption caused major disturbances in the geology and hydrology of the watershed. The short five-year post eruption period of record has not provided the full range of possible events needed to predict future conditions with a normal degree of analytical precision.

Sediment erosion with deposition is partly responsible for potential flooding in the Cowlitz River. This deposition is highly dependent on storm runoff and volcanic activity. Low probability storms (greater than 20-year frequency) have the potential to move large volumes of sediment (see Table II-3) in a few days. These low probability events could create short term sediment problems, but do not have as significant an effect as mudflows on total projected sediment yields. As discussed in Appendix A, volcanically-caused mudflows not only can provide large volumes of sediment in a few short hours, but they also can disturb the stream channels and result in long-term instability. Volcanic activity and mudflows are expected to result in magnitudes of material similar to the experience of the past five years for the entire 50-year study period, making them a dominant sediment-producing process.

The eruption also altered the hydrology of the watershed by altering vegetation and stream characteristics. A return of the watershed to conditions approximating preeruption conditions in all aspects would need to occur for flood peaks and associated flood risks to be significantly reduced without action.

Principle areas where vegetation is returning are the side slopes of the area between the N-1 structure and the mountain. The material included in the

sediment budget comes not from these side slopes but from the debris avalanche (deposited in the river valley by the original eruption). There is little evidence of natural recovery on the avalanche. The deposition of this material varies - with depths to 600 feet. Erosion channels move back and forth across the avalanche, cutting at the sides of the channel and eroding the material. Some of these channels are over 50 feet deep with little chance of stabilizing this material through revegetation. The small amount of vegetation that would establish on the avalanche would eventually be undermined through the erosion process. The result of the lack of natural recovery has been an increase in the discharge of low probability events. The three Toutle River tributaries, the North Fork, South Fork and Green River, used to have gravel and cobble beds. The riverbeds are now largely sand and gravel. All three tributaries now peak at about the same time (this did not happen prior to the eruption). The result of these hydrologic changes is that the peak discharge for any storm event is higher than it was before 1980, and will remain so over the next 50 years unless significant restoration of the watershed occurs.

The key factors to consider in recommending a solution to potential flooding problems in the affected area are:

economic cost of each measure,
environmental values and impacts,
risks associated with each alternative,
and, uncertainty of future sediment yield.

The economic cost of a measure includes not only the cost of implementing the measure, but also the residual damages that would still occur once the measure is in-place and functioning. The impact that a measure or alternative will have on the environmental resources in the affected area must also be considered. Each alternative has environmental pros and cons. The "risk" of a particular measure or alternative relates not only to the degree of flood protection it provides, but also to the degree to which the measure can handle major influxes of sediment from a low probability storm or mudflow without a significant reduction in protection against subsequent storms in the same water year. The solution chosen should be flexible, or able to be modified in future years, to accomodate the uncertainty of future sediment yield.

Summary of Key Decision Document Conclusions (to this point).

General Discussion. As a result of the sediment analysis, the Corps of Engineers developed a sediment budget of 550 mcy (E) to represent the most likely sediment yield during the 50-year project period. If no future action were to be taken to control the sediment, potential flooding along the Cowlitz River would result in average annual damages (at the expected sediment budget) of $43,411,000 per year. With base condition dredging (authorized by Public Law 98-63), damages have been reduced to $16,505,000 per year. The majority of residual damages with base dredging (84 percent) occur in the Kelso area due to a low section of levee. Ten percent of the damages occur in unleveed areas along the 20-mile course of the Cowlitz River below its confluence with the Toutle River. Three percent occur at Castle Rock; two percent at Lexington; and one percent at Longview and the transportation corridor. No damages are included for navigation disruption on the Columbia River as disruption is not anticipated with the current forecast.

Four measures were evaluated during this study in an attempt to address flood damages. These measures were combined into three feasible alternatives for addressing the flooding problem: Dredging based in the Toutle and Cowlitz Rivers, A Single Stage Retention Structure (SRS) with Toutle and Cowlitz River dredging, and a Multiple Staged Retention Structure (MSRS) with associated dredging. All were combined with levee improvements. These alternatives were compared to find the NED plan using the E budget, and a sensitivity analysis was conducted to determine how the NED plan reacts to changes in the sediment budget projection. In all cases, care was taken to assure that each alternative provided comparable levels of protection and residual damages.

Levels of protection provided by the Cowlitz River channel and levees at Longview, Kelso, Lexington, and Castle Rock have been dramatically changed by the eruption and subsequent natural events and recovery actions. Table VI-1 illustrates this point and shows the protection levels achieved with the alternatives in place. It should be recognized that protection levels for the dredging alternative may be lower at some points in any given water year if low probability events deliver sediment at rates that exceed available dredging capacity.

TABLE VI-1
PROTECTION LEVELS
(average exceedence interval, years)

	Pre-Eruption	Base Dredging w/Exist. Levees	Intermediate Dredging + Levees (KL)	SRS, Base-Plus Dredging Plus Levee (KL)
Longview	100-year1/	71-year	167-year	167-year
Kelso	100-year1/	3-year	143-year	143-year
Lexington	less than2/ 10-year	77-year	167-year	167-year
Castle Rock	greater than3/ 100-year	71-year	118-year	118-year

1/ Based on Portland District interim letter report, entitled, Drainage District Condition Study on Safe Water Surface Levels, dated May 1978. One-hundred-year PSP is the minimum level which existed. Freeboard of 10 feet (at Longview) and 5 feet (at Kelso) were not incorporated into this protection level determination (i.e. the PSP was probably greater).

2/ Inside toe of levee prior to the 1980 eruption was used as the safe height for PSP determination.

3/ Three-feet below the crest of Castle Rock levee prior to the 1980 eruption was used as the safe levee height and for determination of PSP.

The alternative displaying the greatest net benefits (benefits minus cost expressed in dollars per year) - the NED plan - consisted of:

- an SRS (125-foot spillway crest) at the Green River site
- dredging along the Cowlitz and Toutle Rivers in the first year of construction
- outyear dredging along the Cowlitz River beginning in year 2000
- and a minimal levee improvement at Kelso.

The analysis conducted to determine the NED plan's sensitivity to changes in projected sediment yield indicated that for a yield of 0.64 E or less, intermediate dredging in the Toutle River initially and then in the Cowlitz River, and minimal levee improvements at Kelso, would be the best economic choice.

If the sediment budget were expected to be less than 0.64 E, the NED plan would consist of anticipatory dredging through the establishment and maintenance of sediment stabilization basins (SSB's) and minimal levee improvements at Kelso. These basins slow the velocity of water by overdredging the channel bottom to create a sump to trap sediment material. Nearly all the material dredged under the 0.64 E budget would be dredged on the Toutle River.

The environmental effects of the alternative plans are also sensitive to sediment delivery, but the effects for the E budget are summarized below.

TABLE VI-2
COMPARISON OF ENVIRONMENTAL EFFECTS
FOR SRS AND DREDGING ALTERNATIVES

SRS/DREDGING/LEVEE	DREDGING/LEVEES
° 5207 acres of land required for SRS and other facilities (3200 acres of which would be impacted by retained sediment)	° N/A
° 1300 acres of land required for inital and outyear dredging	° 4400 total acres of land required for annual dredging
° More rapid recovery of downstream habitat along Toutle River due to reduced sediment movement.	° Recovery of downstream habitat along Toutle River delayed by continued sediment movement
° Natural recovery in reservoir area not effective until reservoir filled.	° N/A
° Natural recovery in disposal areas will occur as sites reach capacity and will be more rapid because 44 mcy would be placed.	° Natural recovery will occur as sites reach capacity and will be slower because 134 mcy would be placed.

SRS/DREDGING/LEVEE	DREDGING/LEVEES
° Natural recovery in levee areas depends on construction period; these are already disturbed areas.	° Natural recovery in levee areas depends on construction period; these are already disturbed areas.
° Increased turbidity each of the 32 years when dredging occurs.	° Increased turbidity each of the 50 years when dredging occurs.
° Possible increased water temperature.	° No effect anticipated.
° Relocation of residents upstream from structure required; businesses and residents in disposal areas must be relocated; open space reduced; increased community viability and stability downstream.	° Businesses and residents in disposal areas must be relocated; open space reduced.
° Fish passage in Toutle River blocked by structure; mitigation required.	° No blockage of fish passage due to dredging (assuming required dredging can be coordinated with annual fish migrations).
° Loss of habitat due to sedimentation upstream from structure.	° Potential for major disruption of fish migration and loss of wildlife habitat due to sediment deposition and dredging following low probability storm or mudflow.
° Recovery of downstream channel and habitat more rapid.	° Recovery of downstream channel and habitat slower.

As the volume of material actually delivered to the waterway requiring dredging is reduced, the impacts of all plans are reduced accordingly. Conversely, an increase in the volume of material deposited also increases the impacts of all plans.

SEDIMENT BUDGET DEVELOPMENT

The 550 mcy erosion forecast presented in Appendix A was used to evaluate the alternatives in this report and is based on two main conditions:

1) Volcanically-caused mudflow activity will continue at 1981-1985 levels for the next 50 years.

2) Hydrologic erosion of sediments will continue beyond the project life until sediment sources have been depleted.

Volcanically-caused mudflows and the resulting erosion is estimated to continue at the observed average rate of 5 mcy per year, removing 250 mcy from the avalanche over the next 50 years. This mudflow activity will keep stream channels upstream from Coldwater Creek unstable, contributing, in part, to an additional 75 mcy of hydrologic erosion. In addition, hydrologic erosion of non-mudflow related sediments is primarily expected to occur downstream from Coldwater Creek. This will result in the erosion of 115 mcy of avalanche and alluvial deposits, for a total of 440 mcy. The above estimates were reviewed by expert consultants and, as a result of their comments following their review, the overall estimate was increased by 25 percent (110 mcy) to 550 mcy. The table below summarizes the sediment budget calculation.

TABLE VI-3

SEDIMENT SOURCES AND VOLUMES

(Based on E Budget)

Source	Sediment Yield (Volume, mcy)	(% of Total 550 mcy Budget)
Mudflow generated	250	45%
Hydrologic erosion upstream from Coldwater Creek (Related in part to mudflow activities)	75	14%
Hydrologic erosion downstream from Coldwater Creek	115	21%
Incorporation of consultants review	110	20%
	550	100%

The sediment forecast was systematically developed, with each element interrelated with the rest. Acceptance of conditions other than those used in developing the E estimate could result in a significant, but indeterminate revision to the sediment forecast. For instance, if the mudflow component were to be reduced significantly, separate studies would be required to determine the hydrologic component of the budget. Of particular concern to this study are conditions which would result in revised sediment forecasts that could change the selection of the preferred solution. The sensitivity analysis results indicate that forecasts of less than 0.64 E or greater than E would alter the NED plan. If sediment yields were less than 0.64 E, dredging could become the NED plan. The sensitivity analysis beginning on page IV-17 summarizes conditions which could lead toward forecasts of 1/2 and 1-1/2 E.

SUMMARY DECISION MATRIX

The summary decision matrix shown as Table VI-4 is provided to assist decision makers who have differing objectives, concerns and premises upon which to assess the likely sediment budget. The sensitivity analysis demonstrates that the NED plan will be different if the sediment budget were to be less than 0.64 E. Because the sediment budget and likely extent of natural recovery can not be known with certainty, decision makers should be aware of the implications of their choice. For example, if the SRS is chosen and the sediment budget proves to be less than 0.64 E, a loss of NED will be realized and a permanent blockage of the Toutle River will have been constructed. On the other hand, if dredging is chosen and the sediment proves to be equal to E, a loss of NED will have occurred and significant amounts of sediment will have to be disposed of along the Cowlitz River. Table VI-4 is designed to highlight all the relevant decision aspects of these choices and situations that may occur. For any selection of an alternative, it is possible to identify the premises that could support such a choice.

TABLE VI-4
SUMMARY CHOICE MATRIX FOR DECISION MAKERS (DM)

I	II	III	IV	V	VI	VII
If DM believe	If DM believe	If DM believe	If DM believe	If DM believe	If DM believe	If DM believe
Sed. budget will be less than 0.64 E and/or	There is uncertainty in sed. budget, but feel it will be >0.64 E, and if they are uncertain about natural recovery and/or	Sed. budget will be >0.64 E and ≤E and	Sed. budget >E and/or	Sed. budget will be less than (<)0.64 E, and/or	There is uncertainty in sed. budget, but expect it will be <0.64 E and/or	Sediment budget will exceed 0.64 E and/or
					They are uncertain about natural recovery, but feel it will be substantial and/or	They believe watershed will return to pre-eruption hydrology and/or
SRS is Env. Less Damaging than Dredging	SRS is Env. Less Damaging than Dredging	SRS is Env. Less Damaging than Dredging	SRS is Env. Less Damaging than Dredging	Dredging is env. less damaging than SRS	Dredging is env. less damaging than SRS	Dredging is env. less damaging than SRS
If DM wish to	If DM wish to	If DM wish to	If DM wish to	If DM wish to	If DM wish to	If DM wish to
Assure certainty offered by SRS solution and/or	Assure certainty offered by SRS solution	Assure certainty offered by SRS solution and/or	Assure certainty offered by SRS solution and/or	Maximize NED and/or Emphasize EQ	Maintain greater flexibility to adjust plan to the sed. realized over time	Maintain greater flexibility to adjust plan to the sed. realized over time
Minimize risk from low probability single or sequential events and/or						Choose env. best solution
Emphasize EQ		Maximize NED and EQ elements	Maximize NED and EQ elements			
If DM are willing to	If DM are willing to	If DM are willing to	If DM are willing to	If DM are willing to	If DM are willing to	If DM are willing to
Forego NED for EQ and/or Forego NED for risk aversion				Risk temporarily reduced levels of protection from low probability single or sequential events	Risk temporarily reduced levels of protection from low probability single or sequential events	Risk temporarily reduced levels of protection from low probability single or sequential events
Forego opportunity to adjust response to realized sediment				Forego certainty of SRS solution	Forego certainty of SRS solution	Forego certainty of SRS solution
Risk financial loss of NED if Sed.<0.64 E	Risk financial loss of NED if Sed.<0.64 E	Risk financial loss of NED if Sed.<0.64 E	Risk financial loss of NED if Sed.<0.64 E	Risk financial loss of NED if sed. >0.64 E	Risk financial loss of NED if sed. >0.64 E	Accept financial loss of NED
Minor dredge in outyears	Dredge or build stages(s) in outyears	Dredge or build stage(s) in outyears	Dredge or build stage(s) in outyears	Commit to long-term management of a dredging program	Commit to long-term management of a dredging program	Commit to long-term management of a dredging program
Budget for larger outlay in initial years.	Budget for larger outlay in initial years.	Budget for larger outlay in initial years.	Budget for larger outlay in initial years.	Commit to budgeting for dredging costs on an annual basis	Commit to budgeting for dredging costs on an annual basis	Commit to budgeting for dredging costs on an annual basis
					Delay decision on SRS with possibility for construction of SRS at later date	Delay decision on SRS with possibility for construction of SRS at later date
DM would select	DM would select	DM would select	DM would select	DM would select	DM would select	DM would select
125-Foot SRS	125-Foot SRS	125-Foot SRS	125-Foot SRS and Plan for and build a second stage above 125' in outyears or a 150-Foot SRS	Dredging	Dredging	Dredging

CHAPTER VII - RECOMMENDED PLAN OF THE DISTRICT ENGINEER

CONCLUSIONS

The objective of this study was to identify the best plan to reduce flood damages to an acceptable level in accordance with guidance from Principles and Guidelines and sound professional judgment. Identification of the sediment budget to be used for plan formulation is the key to the decision process. Given the uncertainties, 550 mcy represents our best professional analysis of what the sediment budget should be. Based upon the expected sediment budget and the considerations in Chapter VI, I conclude that:

1. The potential for flooding in communities along the Cowlitz River and damage to the transportation corridor require implementation of permanent measures to manage the risk created by the movement of sediment in Toutle and Cowlitz Rivers.

2. Based on the analysis performed during this study, a plan consisting of a single retention structure on North Fork Toutle River at the Green River site, minimal levee improvements at Kelso and supplemental downstream dredging best meet the objective of developing a long-term plan to deal with flood problems resulting from the Mount St. Helens eruption. This plan also achieves the highest economic efficiency consistent with preservation of life and property and effectively deals with variations in quantities of sediment delivery. Minimum levee improvements may be accomplished under authority of PL 98-63.

3. This recommended plan provides more flexibility and safety in managing the unique sedimentation and flooding problem presented by the Mount St. Helens eruption than a dredging only or dredging and minimal levee raise strategy.

4. What we now know about the sediment budget, as presented in this report, shows a need to construct a permanent solution.

5. Coordination with nationwide experts in the field of sedimentation indicates that reported sediment predictions reflect the experience of the last five years and represent the best estimate to be made at this time. Because of the uncertainties associated with volcanic and hydrologic events, we will continue to monitor sediment movement to learn more about sediment deposition over time and the associated risks.

6. The Congress has established a Federal role in flood damage reduction. However, the flood problems stemming from the after-effects of the Mount St. Helens eruption created a unique situation. Past Federal emergency efforts, the Presidential commitment to respond to any future life or property threatening emergency and to prepare a Comprehensive Plan, and passage of PL 98-63 and PL 99-88 all attest to the concern with the flood threat along the Cowlitz and Toutle rivers.

7. Study of the expected sediment budget and application of the choice matrix presented in Chapter VI leads me to conclude that the selection of alternative III, a 125-foot SRS, is the best plan to meet the stated objective. In Chapter IV, this SRS with base-plus dredging during 1986 and between years 2000 and 2035, and a levee improvement at Kelso was identified as the NED plan.

8. A single retention structure on the North Fork Toutle River at the Green River site will impede fish passage into the upper Toutle above the structure. Initial design and construction includes facilities for fish passage using trap and hauling methods.

9. Requirements for annual sediment removal by downstream dredging during later project years will be analyzed each year. A comparison of the cost of this dredging versus raising the retention structure should be undertaken. To this end, no provisions should be made initially to preclude raising a completed structure above the preferred height if future conditions warrant. PL 99-88, which authorizes the Single Retention Structure with downstream action, is flexible enough to allow for raising of the structure if that proves more economical than outyear dredging.

OVERVIEW

The NED plan is a combination of three measures: the 125-foot spillway SRS at the Green River site, minimal levee improvement at Kelso, Washington, and downstream dredging both during construction and with reservoir infill in later project years. The Principles and Guidelines used for Federal studies require designation of the NED plan as the preferred one unless overwhelming evidence justifies another selection. All the evidence supports this plan. It provides the greatest net benefits. It requires limited environmental mitigation. Finally, it provides flexibility to deal with uncertainties about sediment volumes and transportation.

During public and agency review of the Comprehensive Plan and Feasibility Report, Washington State, local governments, and various agencies supported an SRS upstream of the Green River confluence of the North Fork Toutle River. It was viewed as causing minimum impact to the fishery, land use, and residents. This recommended plan would fulfill the desire of these important groups.

RECOMMENDED PLAN ELEMENTS

The SRS

Description

The design and construction methods employed for this structure reflect normal Corps' dam design criteria and will address safety and operational characteristics. The SRS would be constructed of earth and rockfill materials with a right abutment spillway in rock (see Figure VII-1). It would trap sediment and debris while allowing water to pass through an outlet works or over a spillway. When completed, the structure would rise 227 feet above foundation grade, or 182 feet above the existing ground, and extend 1,680 feet in length with a spillway 500 feet wide.

The first feature constructed under the plan would be a large cofferdam upstream from the structure site and the right abutment outlet works. The cofferdam would serve two purposes: (1) to divert river flows around the

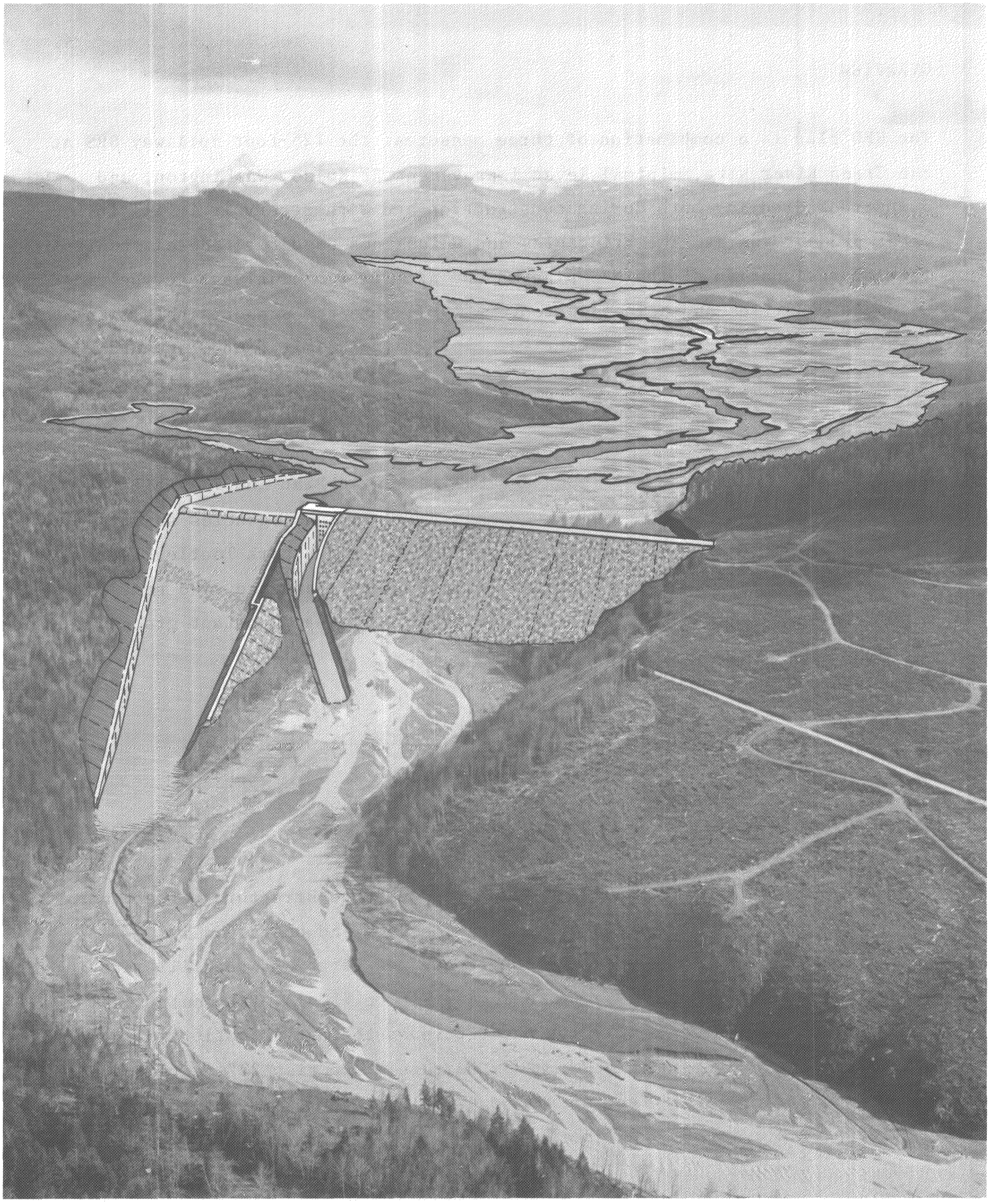


FIGURE VII-1: EMBANKMENT SRS

worksite; and (2) to serve as a small interim sediment retention structure. Retention of sediment behind the cofferdam at the earliest possible date will significantly reduce early year downstream actions. Once the main structure embankment is constructed to a functional elevation higher than the cofferdam, the cofferdam will be incorporated either into the embankment or the impoundment area behind the main structure.

The main spillway would be built 125 feet above the existing streambed. Given normal hydrologic conditions, this height will provide capacity adequate to capture most problem-causing sediment anticipated to erode from the debris avalanche between 1987 and 2035. Using the unregulated outlet works in the structure permits a natural variation of the size and depth of the pool extending upstream behind the structure for retaining sediment produced during various storm events. During major storms, large pools would form, allowing material to settle out prior to reaching the structure and outlet works and thereby increasing the actual retention capability of the structure. The structure in its present design not only retains sediment but also provides some initial flow control through the outlet works and later with the spillway. However, flow control declines over time as the pool fills and is considered incidental to the structure. No benefits are claimed.

The structure was tested for both the 213,000 cfs Probable Maximum Flood (PMF) and the 75 mcy Operating Basis Mudflow (OBM) to compare with- and without-project conditions. The flood will be passed and the mudflow either contained or passed without causing greater than without-project damage for the 50-year operational life. In addition, the sediment delivered by a 100-year flood would be trapped until 1991.

<u>Preliminary Design of the Structure</u>: Continued analysis of the SRS site indicates the foundation is composed of competent basalt and dense gravels, indicating adequate support is available for the proposed structure. All studies were made to satisfy existing Corps' design standards.

<u>Sizing of the Spillway</u>: Under normal conditions, a spillway is sized to pass the PMF. However, given the instability of the upper Toutle River Basin and the necessity for providing the greatest possible margin of safety, the

spillway for the retention structure is sized to pass the OBM. The design assumes that Spirit Lake and other upper basin lakes are stabilized. Therefore, hypothetical lake breakouts were not used as a basis for sizing the spillway. Table VII-1 shows the peak discharges at the SRS site for normal annual flows, low frequency floods, the probable maximum flood and the operating basis mudflow.

TABLE VII-1
PEAK DISCHARGES FOR NORMAL AND POSSIBLE FLOWS
AT GREEN RIVER SRS LOCATION

Type of Flow	Peak Discharge (cfs)
Mean Daily Flow	1,254
2-Year Flood	13,100
10-Year Flood	19,600
50-Year Flood	26,100
100-Year Flood	30,800
500-Year Flood	43,000
Probable Maximum Flood (PMF)	206,000
Operating Basis Mudflow (OBM)	228,000

As Table VII-1 indicates, the peak discharge for the PMF is 206,000 cfs and peak discharge for the OBM is 228,000 cfs. Therefore, the OBM is the design flow for the spillway.

As sediment infills behind the structure, available storage is ultimately decreased to a run of river configuration. A determination for an additional height of structure and spillway crest may be required to continue storage. This would substitute for dredging in out years.

Levee Improvements

Description

The safe height of the existing levee at Kelso will be raised through improvements to the oversteepened backslopes. Improvements would bring the levee, which runs from Cowlitz RM 1.3 to RM 7 (see Figure VII-2), up to Corps' standards. The emergency levee structures, constructed in 1982, would be removed as necessary from the existing permanent levees to allow construction of the improvements. Deficient levee sections would then be improved by adding fill to the overly steep landward slopes, revetting riverward slopes where required, and seeding the new fill embankments.

Downstream Dredging

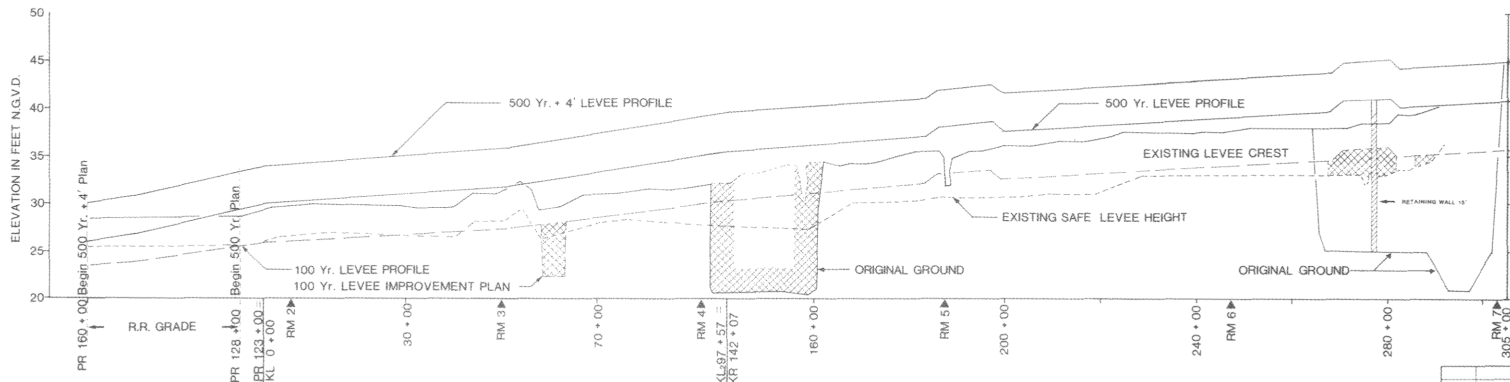
Approximately 17 mcy of sediment will be dredged during the first year of construction and 27 mcy after the reservoir fills and materials begin to pass over the spillway. Most of this total, 32 mcy, will be taken from Cowlitz RM 10 to 20. Disposal sites along the Cowlitz River would receive the dredged materials.

Mitigation

Mitigation for North Fork Toutle River fish runs will be provided by a fish bypass facility. Adults would be trapped at the foot of the SRS and hauled upstream in vehicles. Juveniles would pass downstream throughout the outlet works and spillway of the structure. Initial cost of the bypass is estimated at $1.3 M. Annual operation and maintenance would be $0.1 M. Lands acquired for the reservoir would be managed for wildlife habitat. Limited initial seeding and fertilization would be approximately $1,000 per acre. Refertilization would be required for three years at $500 per acre per year.

Mitigation for dredging operations is dependent upon the category of habitat value for each disposal site used.

PLAN 0 500 1000 1500 SCALE IN FEET



KELSO LEVEE PROFILE

REVISION	DATE	DESCRIPTION	BY

Mount St. Helens, Washington
DECISION DOCUMENT
KELSO LEVEE

SUPERVISED | DESIGNED | DRAWN | CHECKED
CHIEF, DESIGN BRANCH
DATE | SHEET | PLATE

FIGURE VII-2

Category 1 sites are wetlands and other high value lands. Mitigation for this category would consist of replacement land purchase and habitat enhancement at $4,500 per acre and reshaping and revegetation of disposal sites at an additional $3,000 per acre.

Category 2 sites are not as highly valued as habitat. Mitigation for selection and use of these sites would be some mitigation land purchase revegetation at $3,000 per acre.

Category 3 sites require no mitigation land acquisition, but disposal sites would require revegetation at $3,000 per acre.

Levee construction would require no separate mitigation because the existing levees are already low value habitat. It is expected, however, that surfaces of the levee that are not riprapped would be seeded for erosion control.

With the recommended SRS (NED) plan in place and Cowlitz River outyear dredging, damage of $10,600,000 would not be incurred at the transportation corridor until a flood of approximately 500-year recurrence interval occurs.

REAL ESTATE

The SRS requires 5,207 acres of land above the North Fork Toutle RM 13.0 for the structure and reservoir based on the 125-foot spillway height. Dredging requires approximatey 25 different disposal sites for a total of approximately 1,300 acres. Small amounts of land are required for the levee improvements which will require additional sponsorship.

COST ESTIMATE

Table VII-2 shows the costs of this plan. The expenditures for the SRS, levees, and dredging are detailed. This program will cost $231.1 million in 1985 dollars. Construction of the SRS, fish bypass, and levees accounts for

$65.7 million of those costs. Initial dredging accounts for another $25.4 million and real estate and relocations are $18 million. Other costs, including O&M, monitoring, and outyear dredging total $122 million.

ECONOMIC SUMMARY

The net benefits of this plan are $18,362,000 annually. This is the most beneficial program with the 550 mcy sediment budget and for modeled sediment deliveries above 350 mcy. Average annual costs for this program are $9.38 million compared to $13.35 million for the best combination of dredging/levee raise measures.

ENVIRONMENTAL SUMMARY

The recommended plan is environmentally advantageous to plans maintaining channel geometry solely by dredging. Potentially substantial impacts of extensive dredged material disposal sites are minimized. Mitigation of fish runs can be carried out by standard programs. Flood control without major land use, social, and economic disruptions to local residents are possible with this plan.

LOCAL SPONSORSHIP

The State of Washington, Cowlitz County, and other local interests have contributed to Federal emergency actions since the eruption. In addition to maintaining the Cowlitz County Flood Warning System, the state has spent $1 million to procure disposal sites for dredged material and another $3.5 million (State Senate Bill 3519) was expended for related activities. For example, the state acquired lands at the Lower Toutle sediment stabilization basins LT-1 and LT-3, where dredging is continuing. After erosion threatened the abutments of the I-5 bridge, the State of Washington Department of Transportation placed revetment and sheet pile at the bridge to prevent further damage and possible closure of this major transportation route.

TABLE VII-2

TOTAL PROJECT COST

125-FOOT SRS WITH COWLITZ BASE-PLUS DREDGING AND KL MINIMUM LEVEE

($000,000)

Total Project Cost

SRS		98.9
Construction	63.7	
O&M	16.1	
Monitoring	5.2	
Real Estate	12.2	
Relocation	0.4	
Mitigation	1.3	
Dredging		84.8
Construction	76.15	
Real Estate	4.32	
Mitigation	4.33	
Levee (KL Min. Levee)		2.8
Cost	0.74	
Real Estate	1.10	
O&M	0.96	
Other		44.6
Revetment	0.00	
Disposal Site Rehab.	6.80	
D/S Monitoring	37.80	
	TOTAL PROJECT COST	231.1

Within Cowlitz County, local sponsors signed cooperative agreements to provide lands, easements and rights-of-way for emergency levee raising. To date, the local governments have expended approximately $7.4 million on activities resulting from the eruption of Mount St. Helens.

The State of Washington and Cowlitz County have indicated their willingness to share in the cost of a solution to the potential flood problem by setting aside $12.9 million and $4 million, respectively, toward the local share of project costs.

RECOMMENDATION

This decision document has been prepared to satisfy the recommendations that the Chief of Engineers forwarded to the Assistant Secretary of the Army in the draft legislation which accompanied his 7 May 1985 submittal of the Mount St. Helens Feasibility Report. The purpose of the continuing studies is to insure that the best solution is ultimately selected for implementation. After carefully considering the uncertainties associated with estimating volume, movement, and deposition of sediment moving in the Toutle and Cowlitz Rivers and after evaluating the environmental, social, and economic impacts of measures for controlling Mount St. Helens sediments, I find no compelling or convincing new evidence to justify selection of a staged sediment retention structure or dredging alternative. Therefore, based upon the preceding analysis, I recommend that the Acting Assistant Secretary of the Army for Civil Works implement the construction of a sediment retention structure, with a 125-foot spillway height, on the North Fork Toutle River with associated downstream dredging and implement improvements to the levee at Kelso, Washington.

Gary R. Lord

GARY R. LORD
Colonel, Corps of Engineers
District Engineer

APPENDIX A

MOUNT ST. HELENS

Sedimentation Study/1985

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INTRODUCTION

Purpose

This appendix updates the 1985 long range sediment forecast for the Toutle-Cowlitz-Columbia river system and documents the rational behind that forecast. The sediment forecast is the basis for planning and designing of permanent sediment control measures.

Sediment Forecast Summary

This 1985 study is the third in a series of long term sediment forecasts made by the Corps of Engineers (COE) for the Toutle, Cowlitz and Columbia Rivers. It is based on a larger data base and more detailed analyses than earlier forecasts. The expanded data base includes 4 photogrammetric surveys of the avalanche, an additional one-and-one-half years of suspended-sediment data, five additional Cowlitz River surveys, and more information on the unit weight and gradation of the materials.

The composition, erosion, and geomorphic development of the debris avalanche was analyzed to determine existing erosion rates and the availability of the sediment sources. Suspended-sediment records and cross-section surveys on the Toutle River were used to determine its role in the sedimentation process. Suspended-sediment records, cross-section surveys, dredging records and bed material samples were analyzed to determine the responses of the Cowlitz and Columbia rivers to observed sediment inflows. The principle conclusions of this forecast are summarized below and described in detail in Sections 2 and 3.

1. Avalanche erosion is estimated to be 23 million cubic yards (mcy) in water year (WY) 1986, declining to about 13 mcy by WY 2000 and to slightly more than 6 mcy in WY 2035. This would result in approximately 630 mcy of erosion between 1980 and 2035 (80 mcy 1980-1985 and 550 mcy 1986-2035).

2. The Toutle River would only be a minor sediment source.

3. Cowlitz River deposition is forecast to reach nearly 120 mcy by 2035, with 80 percent of that volume upstream of River Mile (RM) 10.

4. Deposition in the Columbia River will be minimal and is not expected to be a significant problem except under extreme hydrologic or mudflow conditions.

Previous Sediment Forecasts

Comprehensive Plan

The first sediment forecast was presented in "A Comprehensive Plan for Responding to the Long-Term Threat Created by the Eruption of Mount St. Helens, Washington" (COE, 1983). That forecast was based on a very limited amount of suspended-sediment measurements and avalanche cross-sections. Predicted erosion was based on the observed rate of erosion, and a theoretical equilibrium profile and channel geometry in the avalanche. Cowlitz River deposition was estimated from sediment transport modeling using the COE's HEC-6 computer program "Scour and Deposition in Rivers and Reservoirs". A mass balance was then used to estimate scour and deposition in the remainder of the system. The principle conclusions of the Comprehensive Plan sediment forecast were:

1. Sediment erosion from the avalanche would average 50 mcy cubic yards (mcy) per year for the initial 10 years and would total 1 bcy over 50 years.

2. The Toutle River system acted as a depositional area in the early years and later became a sediment source.

3. Cowlitz River deposition would reach a maximum accumulation of 50 mcy by 1990 and then erode slowly.

4. A total of 240 mcy would have to be dredged from the Columbia River to maintain the navigation channel.

Sedimentation Study/1984

In September 1984, the COE prepared a second long-term sediment forecast report "Mt. St. Helens, Cowlitz and Toutle Rivers, Sedimentation Study/1984" (SS/84). This report was the basis for planning the sediment control measures contained in the "Mount St. Helens, Washington Feasibility Report" (COE, 1984). This second forecast was based on significantly more information than

the first forecast. The most important new information included: two complete years of suspended-sediment measurements on the North Fork Toutle, Toutle, and Cowlitz rivers; geomorphic analysis of the avalanche (OSU, 1984); and additional cross-section surveys on the avalanche and the Cowlitz River.

To predict erosion, the avalanche was divided into subreaches based on distinct geomorphic characteristics. Erosion was then forecast for each sub-reach based on the observed rate of erosion and a geomorphic evaluation of the sediment avaliable. The initial sub-reach rates were balanced against estimates of the erosion caused by various processes. A similiar method was used on the Toutle River. Cowlitz River deposition was again predicted based on sediment transport modeling using the HEC-6 computer program, as was Columbia River deposition. The principle conclusions of the SS/84 sediment forecast were:

1. The forecast erosion would be 28 mcy in WY 1985, declining to 16 mcy per year by the end of the century and to 7 mcy per year by 2034. The total erosion from 1980 through 2034 was estimated to be 750 mcy.

2. The Toutle River would be a sediment source during the first 10 years.

3. Cowlitz River deposition would accumulate to a maximum of 78 mcy and then erode slowly.

4. Columbia River deposition would occur primarily near the mouth of the Cowlitz and would total 145 mcy.

Following is a comparison of the studies conclusions:

Year of Study	Avalanche Erosion Initial Year (mcy)	Avalanche Erosion Total 1980-2035 (mcy)	Cowlitz River Deposition (mcy)	Columbia River Dredging (mcy)
1983	50	1000	50	240
1984	28	750	78	145
1985	23	630	120	0

Critical Elements

The critical elements affecting this sediment forecast are identified below. Each critical element is explained in detail later in this appendix.

Erosion

The observed erosion and geomorphic development on the debris avalanche and the volcanic/mudflow activity of Mount St. Helens are critical elements in determining the initial sediment yields. The total volume of erosion is controlled by the availability of material and the presence of water, either from hydrologic or volcanic events in sufficient volumes to transport the sediment materials. Future hydrologic and volcanic events are critical elements in the long-term forecast. Because of the short period of record and complexity of the analysis, the forecast was reviewed by a group of expert consultatnts which recommended a final adjustment for consideration.

Deposition

The critical elements in determining deposition are the volume and gradation of the sediment inflow, and the transport capabilities of the respective rivers. The impacts of deposition varies depending on its location within the river system.

Study Limitations

The long-term forecasting of sediment erosion, transport, and deposition in a highly disturbed watershed like the Toutle-Cowlitz-Columbia, is complicated by the absence of proven analytical techniques, a short period of record since the May 1980 eruption, and the lack of major storm events which would demonstrate effects of low frequency storm-on-sediment erosion. However, some review was made of significantly disturbed basins in California and a team of Corps experts visited Japan to evaluate volcanic erosion and control works in that country. The data base and analysis methods used to produce this forecast were developed over the past 3 to 5 years. The sediment forecast presented in this report is based on the current level of understanding of the sedimentation processes occurring in the watershed. The COE and USGS monitoring programs have produced a large amount of high quality data which was used to develop a number of theories on the sedimentation processes. However, because of the short period of record, it is difficult to determine the significance of some of the apparent trends. In extreme cases, there may be two or three conflicting theories among experts about the existence, meaning, or significance of some trends.

This sediment forecast is made for average annual hydrologic and volcanic conditions. The hydrologic average is based on over 50 years of streamflows. Individual years vary greatly above and below the average annual discharge. The volcanic average is based on the 4 year period from 1981 to 1985. There are no ways to determine future hydrologic or volcanic events. Therefore, the actual volumes of sediment erosion and deposition in any single year are likely to be significantly above or below those forecast. However, the long-term averages are expected to be similar to the forecast trend.

DEBRIS AVALANCHE EROSION

Introduction, Sediment Forecast

The purpose of the sediment forecast is to evaluate the expected intensity and duration of sediment yields from the debris avalanche. A more thorough discussion of processes of erosion and sediment yields from the debris avalanche can be found in Mt. St. Helens, Cowlitz and Toutle Rivers,

Sedimentation Study/1984. This appendix contains adjusted numbers and projections from studies completed since 1984.

With the estimate of expected sediment yields, it is possible to assess downstream impacts in the Cowlitz and Columbia Rivers for purposes of project formulation. The two major activities of the sediment forecast were to 1) Estimate an initial average annual sediment yield based on post eruption sediment yields, adjusted by a sediment yield simulation technique for a much greater range of hydrology and 2) to estimate the total volume and the rate of decay of erosion from the channel reaches of the debris avalanche.

Initial Average Annual Sediment Yields

The initial average annual sediment yield was the result of calculations of post eruption sediment yields from the debris avalanche adjusted by a suspended sediment simulation technique to incorporate a wider spectrum of flows. An estimate of unmeasured sediment discharge and sediment yields from mudflows was added for the initial average annual sediment yields.

Post Eruption Sediment Yields

The post eruption sediment yields were derived from computations of erosion of sequential cross sections in the debris avalanche and sediment measurements at the Kid Valley USGS stream gage. The results of sediment yields from the two methods can be seen in Table A-1.

TABLE A-1
SEDIMENT YIELDS FROM THE DEBRIS AVALANCHE
COMPARISON OF AVERAGE END AREA AND GAGE DATA
WATER YEARS 1981-1985
IN MILLIONS OF CUBIC YARDS[1]

PERIOD	AVE. END AREA	KID VALLEY GAGE
1981-1982	40	44
1983-1984	39	36
1985	4	4
1981-1985	83	84

1=total tonnage converted to volume by multiplying by 0.67 cubic yards/ton.

As can be seen in Table A-1 approximately 83-84 mcy of sediment was calculated to have eroded from the debris avalanche from water years 1981-1985. The average for the five year period is approximately 17 mcy/year. The post eruptive period has shown a spectrum of flows. A synopsis of post eruption flows based on a cumulative frequency analysis is reported in Table A-2.

TABLE A-2
RECURRENCE INTERVAL OF
MAXIMUM 1-, 7-, AND 183-DAY
TOUTLE RIVER DISCHARGES FOR
WY 1981 to 1985

	Average Exceedence Interval in Years		
Water Year	1 Day	7 Day	183-Day
1981	3	PR 1/	PR 1/
1982	20	10	8
1983	4	4	5
1984	<2	2	2
1985	<2	<2	PR 1/

1/ PR = Partial Record. No analysis possible at this date.

Based on the above cumulative volume frequency analysis, the post eruption period has had two above average years (water years 1982, 1983), one below average (water year 1985), and one average year of stream flow (water year 1984). The 1981 water year is considered to be slightly below average based on a partial record of stream flow and precipitation records.

Sediment Yield Simulation

Because of the short (5-year) post-eruption streamflow and suspended sediment record, a simulation approach was utilized to extend the data set for purposes of determining average sediment yields from the debris avalanche.

Suspended sediment yields were estimated by simulation and estimates for the unmeasured sediment and mudflow discharges were then added for estimates of total sediment load from the debris avalanche for average hydrologic conditions.

Suspended Sediment Simulation

Fifty years of daily suspended sediment records were simulated for the North Fork Toutle River to determine the average sediment yields under a variety of sediment discharge/water discharge relationships (sediment rating curve) and variations of hydrologic conditions. The sediment rating curves are a log/log regression of sediment discharge and water discharge for the 1980-1984 water years (Figure A-1).

Average annual sediment yields were calculated from the regression equation of the sediment rating curves and daily flow from the North Fork Toutle River flow record. Figure A-2 shows the results of the 50 year simulation for the four sediment rating curves. As can be seen in Figure A-2 the 1982, 1983, and 1984 water years sediment rating curves predict similar quantities of sediment yields over the 50 year simulation.

Statistics that estimate central tendencies (such as mean, standard deviation, skewness, and kurtosis) were calculated for the flow record and each sediment rating curve. The average sediment yield for the 4 years of the sediment rating curves were 25, 14, 17, and 13 mcy/year for the 1981, 1982, 1983, and 1984 sediment rating curves, respectively. Statistical calculations of skewness and kurtosis showed a normal distribution, hence an arithmetic mean average of sediment yields is an appropriate conservative estimate of yield.

The 1982 water year suspended sediment rating curve was selected as the best estimate of the expected conditions because it encompassed the widest range of flows. Therefore, the projection for average annual suspended sediment yields under present conditions is 14 mcy.

Unmeasured Sediment Discharge: The unmeasured sediment discharge is the sediment in the stream column that cannot be measured with a suspended sediment sampler, either because the particle is too large to be sampled or it is in transport in the stream column below the orifice of the sampler. The unmeasured sediment load can vary from near zero to well over 200 percent of the measured suspended sediment (Colby, 1957). The unmeasured load on the North Fork Toutle River has been estimated to be 15 percent (or 2 mcy in the first year) of the measured suspended sediment. This estimate is based on

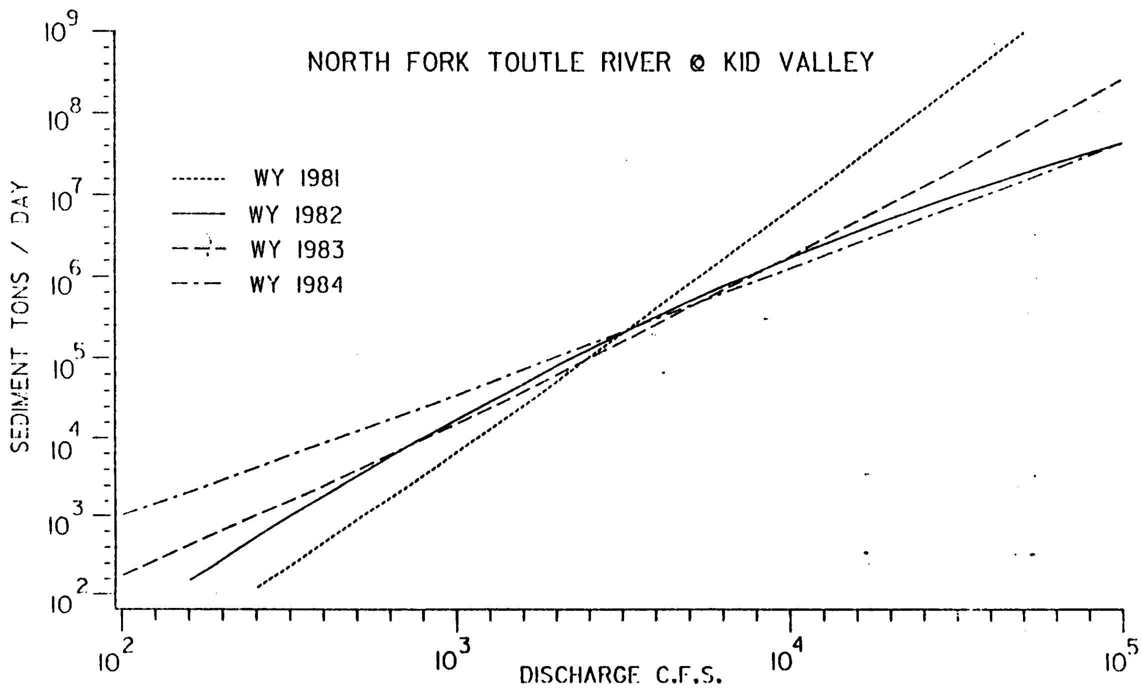


FIGURE A-1: SEDIMENT RATING CURVES

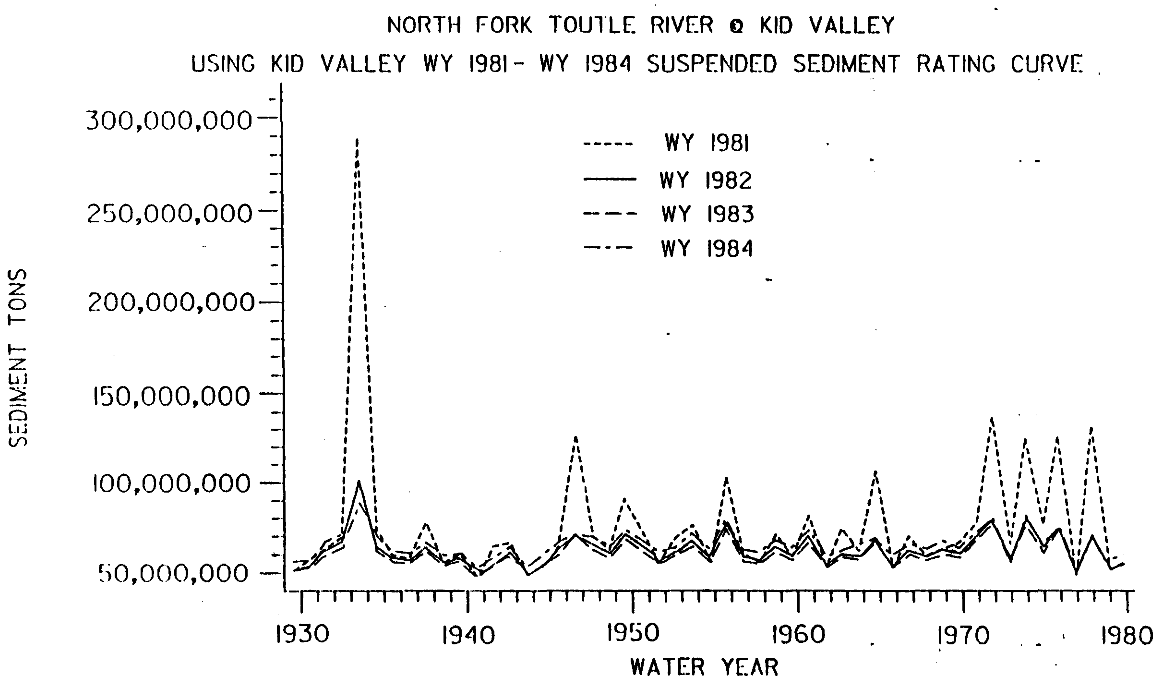


FIGURE A-2: SUSPENDED SEDIMENT SIMULATION

calculations from the Modified Einstein total load sediment transport formula and preliminary measurements from the Helley Smith bedload sampler.

In the absence of a long historical mudflow record or the identiication of a definite trend in eruptive activity, it was assumed the same conditions and processes that have existed over the past 5 years to continue in the immediate future (Figure A-3). Therefore, the best way to estimate the average annual sediment contribution from mudflows is to look at those past 5 years of record. Three significant mudflow events have occurred since 1980 (March 1982, February 1983, and May 1984: Figure A-4). If the total volume of all three events since 1980, 20 mcy was divided by the four full winters with a permanent snow pack, 1981-84 of record the result is a potential 5 mcy of mudflow introduced into the system annually.

In relating maximum total volumes of mudflow to sediment volume, consideration must be given to mudflow sediment concentrations and densities. Mudflow sediment concentrations vary with each event. Assuming an average concentration of 80 percent solids by weight for a mudflow and that avalanche and pyroclastic deposits with a typical density of 110 lbs/ft^3 were the major sources of sediment for a mudflow. Then a mudflow with a volume of 1 mcy and a sediment concentration of 80 percent by weight (60 percent solids by volume), erodes .9 mcy of material. Therefore, an average annual mudflow volume of 5 mcy would erode 4.5 mcy of sediment (5 mcy times .9). Because of the uncertainties associated with mudflow estimates, the volume was kept at 5 mcy.

Some of the sediment carried by a mudflow is deposited downstream before it passes the N-1 Sediment Retention Structure. The quantity of sediment transported past N-1 by a mudflow varies greatly with each event and is dependent on a number of factors, including mudflow volumes, concentrations, routing, channel morphology, and stream flows at the time of an event. The biggest pulse of sediment from a mudflow is transported during the first 2 days of an event, but elevated levels of sediment transport continue for weeks or even months afterwards as the river erodes the soft mudflow deposits. Twenty-five percent of the sediment transported by the March 1982 mudflow passed the Kid Valley gage in the first 2 days. An estimated average of 80 perent of the sediment passes N-1 within a few weeks of the event. The

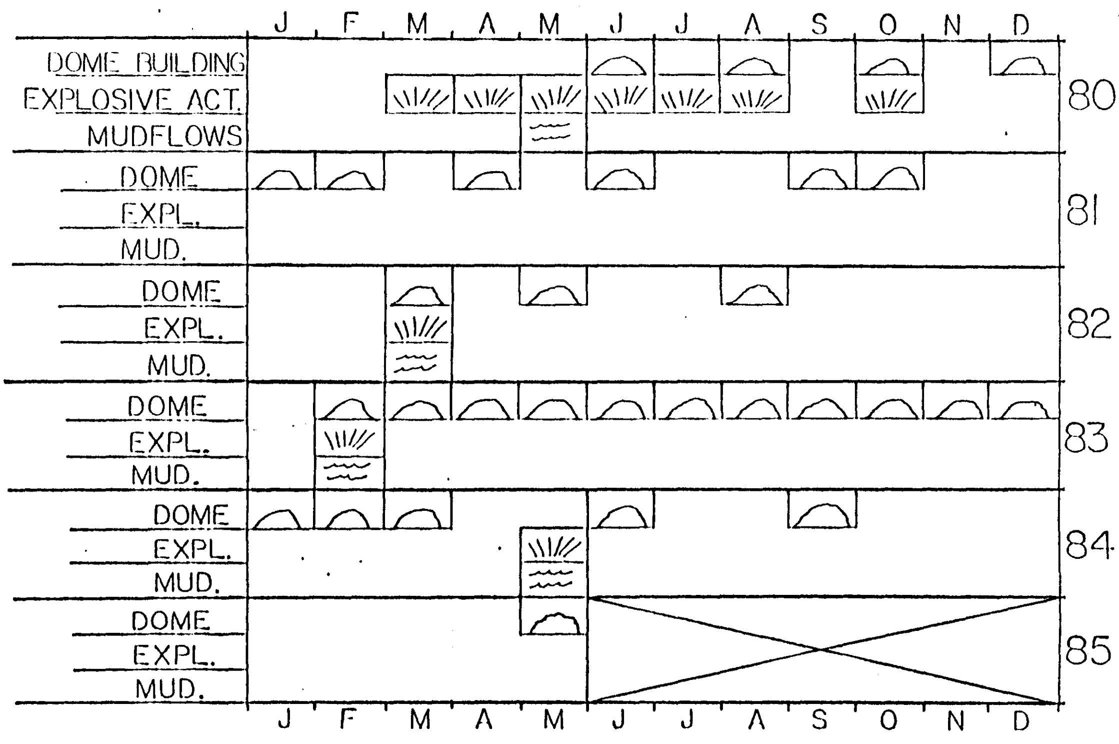


FIGURE A-3: MOUNT ST. HELENS ERUPTIVE ACTIVITY
1980-1985

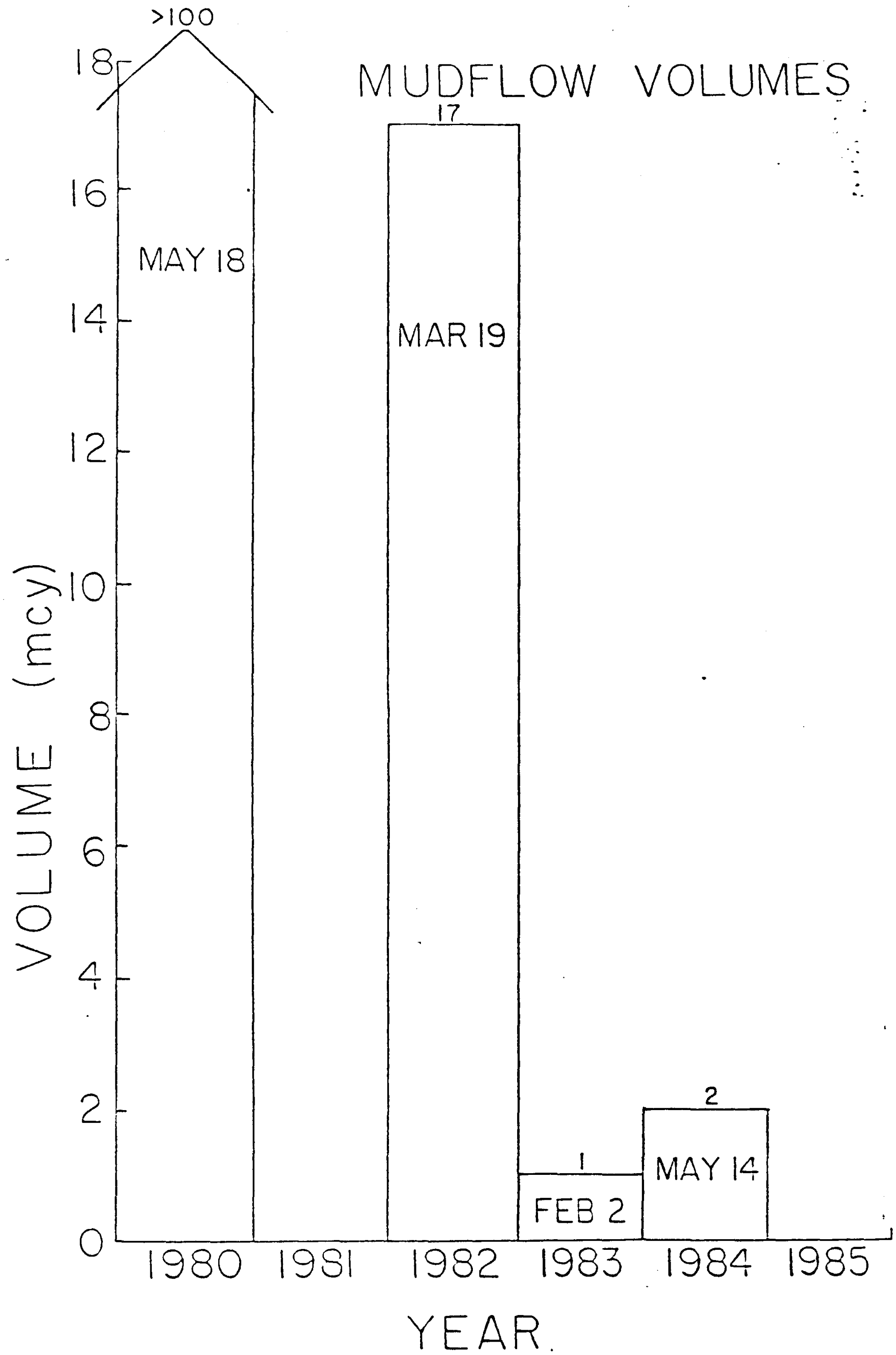


FIGURE A-4: MUDFLOW VOLUMES 1980-1985

material transported after the first 2 days of an event was accounted for in suspended sediment movement. The material transported during the first 2 days of an event is not properly represented in the sediment load curve. To account for the quantity moved during the first 2 days, a separate mudflow factor was added to the annual sediment yield. Using 25 percent of 5 mcy as the estimate for transport during the first 2 days and rounding up to the nearest whole number, results in 2 mcy/yr which must be added to the suspended sediment and unmeasured sediment contribution to determine the initial yield. In conclusion, mudflows are expected to contribute 5 mcy/yr with 2 mcy of that coming during the event, and 3 mcy coming down as part of the long-term average.

Literature Search of Rate of Decay of Sediment Yields

In a watershed that is in an equilibrium condition, the integration of a sediment discharge curve and a flow duration curve would give an average annual sediment yield. Conversely, watersheds that have experienced an intense perturbation can be expected to have high sediment yields immediately after the perturbation which diminish with time (Schumm, 1975). Studies made of sediment yields following watershed disturbances such as fires, logging, and floods are pertinent here. The disturbances from fires and logging are not representative of conditions on the Mount St. Helens debris avalanche but the trends of sediment yields after a disturbance are significant, because they, like the eruption of Mount St. Helens, caused a significant perturbation to the watershed.

Several studies have considered the long-term sedimentation impacts of major flood events. Kelsey (1982) reported on the movement of material deposited in the streambed of the Van Duzen River, California, from the December 1964 flood. Much of the material was deposited by debris avalanches in the headwaters of the stream. Once material entered the perennial streams, sediment transit time out of the study area (160 sq km) was estimated to range from 10 years to 5,000 years, depending on its location in relation to the active channel. Brown and Ritter (1971) concluded that the December 1964 storms doubled the sediment yield rates on the Eel River through processes similar to those observed by Kelsey.

The above studies provide some insight into the future for the debris avalanche. Even though the magnitude of erosion and transport of the Mount St. Helens material is much greater, the general trends observed are applicable. That is, sand and finer material available in the active channel will steadily be eroded away, but the coarser material and material outside the active channel will take a very long time to be discharged from the system.

The Portland District forecast of sediment yields based on a source by source evaluation is explained below. Figure A-5 shows the geographic location of areas discussed.

Forecasted Erosion by Source

Hillslopes

Hillslope erosion was a significant source of sediment immediately following the 1980 eruption. Lehre (1983) estimated that hillslopes contributed approximately 6.1 mcy of sediment to the stream system in water year 1981. Collins (1984) had documented that hillslope erosion decreased to 15% and 7% of the 1981 rate for water years 1982 and 1983. Collins (1984) has projected a rapid decay of the hillslopes as a sediment source (Figure A-6). As a result, hillslope erosion is expected to have no measurable impact on the sediment forecast.

Tributary Channels

The tributary channels consist of the Loowit, Carbonate, Pumice Pond, and other smaller tributaries of the North Fork Toutle River. They are expected to follow the past trend into the future. These tributaries have small drainage areas (1-3 square miles). Due to their small size, stream flow and associated sediment transport is limited, however they are subjected to high annual precipitation and storm events. During the post eruption period, however, these tributaries contributed nearly 4 mcy/year, largely as a result of mudflows from Mount St. Helens and as a response to changes in base level of the N. Fork Toutle River. The upper tributaries, such as the Pumice Pond, Loowit, and Carbonate Creek are expected to show a constant sediment yield

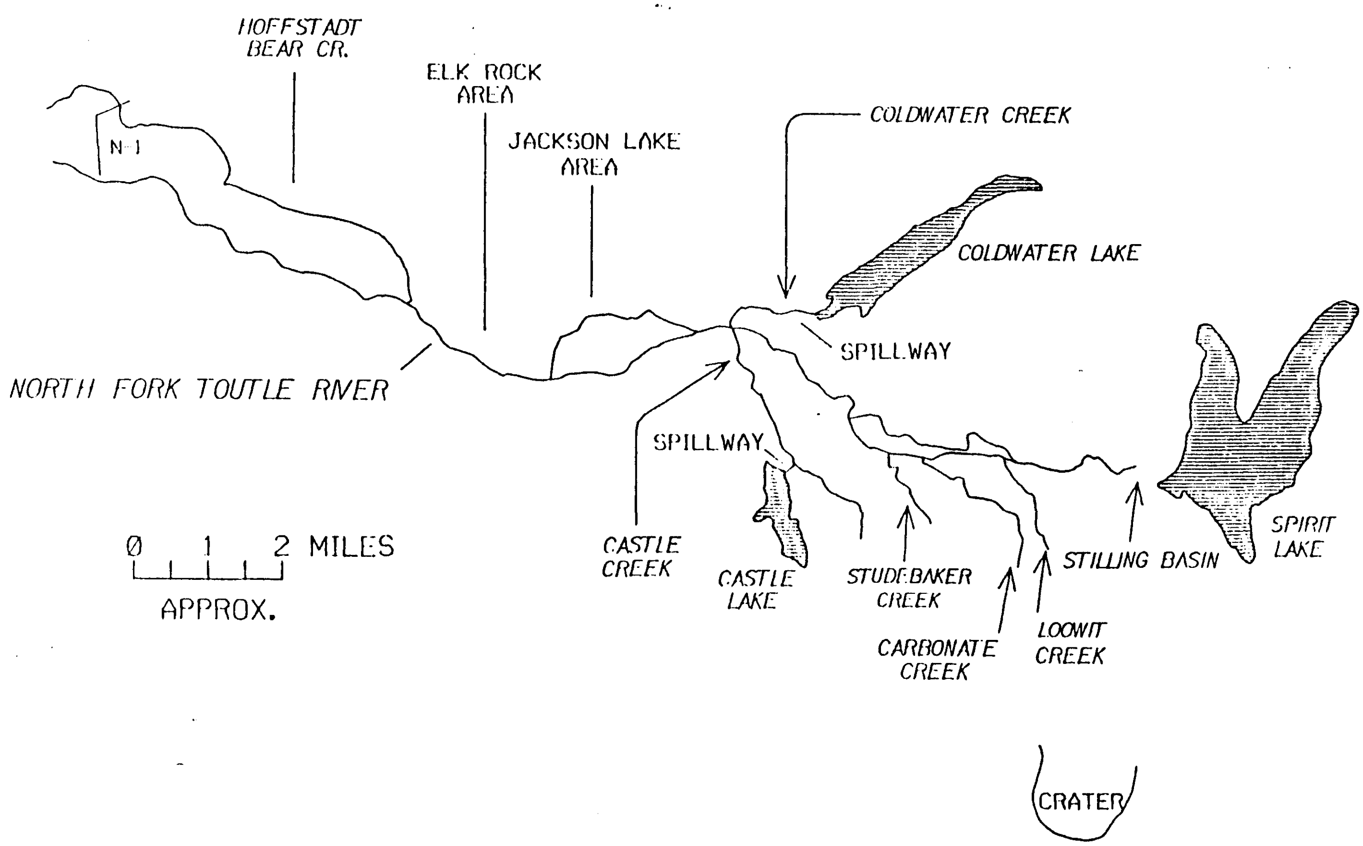


FIGURE A-5: AVALANCHE AREA LOCATION MAP,
NORTH FORK TOUTLE RIVER, WASHINGTON

from mudflows during the next 50 years. The lack of significant decay in sediment yields is because the channels are eroding through a generally fine grained, low bulk density deposit that is periodically disturbed by mudflows. Factors, such as accumulations of coarser aluvium, that may promote a sediment decline, are not expected to occur. As a result, sediment yields from these tributary channels are equal to the present natural rate of sediment production (4-5 mcy/year)through the next 50 years.

The controlled breaching of Coldwater Lake caused nearly 2 mcy of erosion in the late 1981/early 1982 water year. The Coldwater Creek outlet is expected to be stable in the future. Thus, there is no significant sediment yield expected from this channel.

Castle Creek Channel

The Castle Creek channel evolved rapidly after the 1980 eruption through initial incision of the channel. Bank erosion was the most important source of sediment there since WY 1982. Post eruption sediment yields average 2 mcy/year. Sediment yields are expected to decline from 2mcy/year at present to negligible within 8 years for a total of 8 mcy.

North Fork Toutle River

The North Fork Toutle River will be a large source of sediment. The channel can be broken into three distinct morphological reaches: 1) from the Spirit Lake divide to the Coldwater outlet, 2) Coldwater Lake outlet to the Elk Rock valley constriction, and 3) reworked fluvial sediment, from the Coldwater Lake outlet to the N-1 debris retention structure. The distinction is appropriate for purposes of evaluating expected hydrologic and associated sediment transport associated with the Spirit Lake diversion tunnel.

Spirit Lake to Coldwater Outlet: The Spirit Lake to Coldwater reach has developed largely as a response to the Spirit Lake pumping operation. Prior to the inception of pumping, this reach was a depositional area. The pumping operation greatly increased the discharge into the reach. Nearly 22 mcy of sediment has eroded from this reach during the post eruption period but over 16 mcy can be directly attributed to

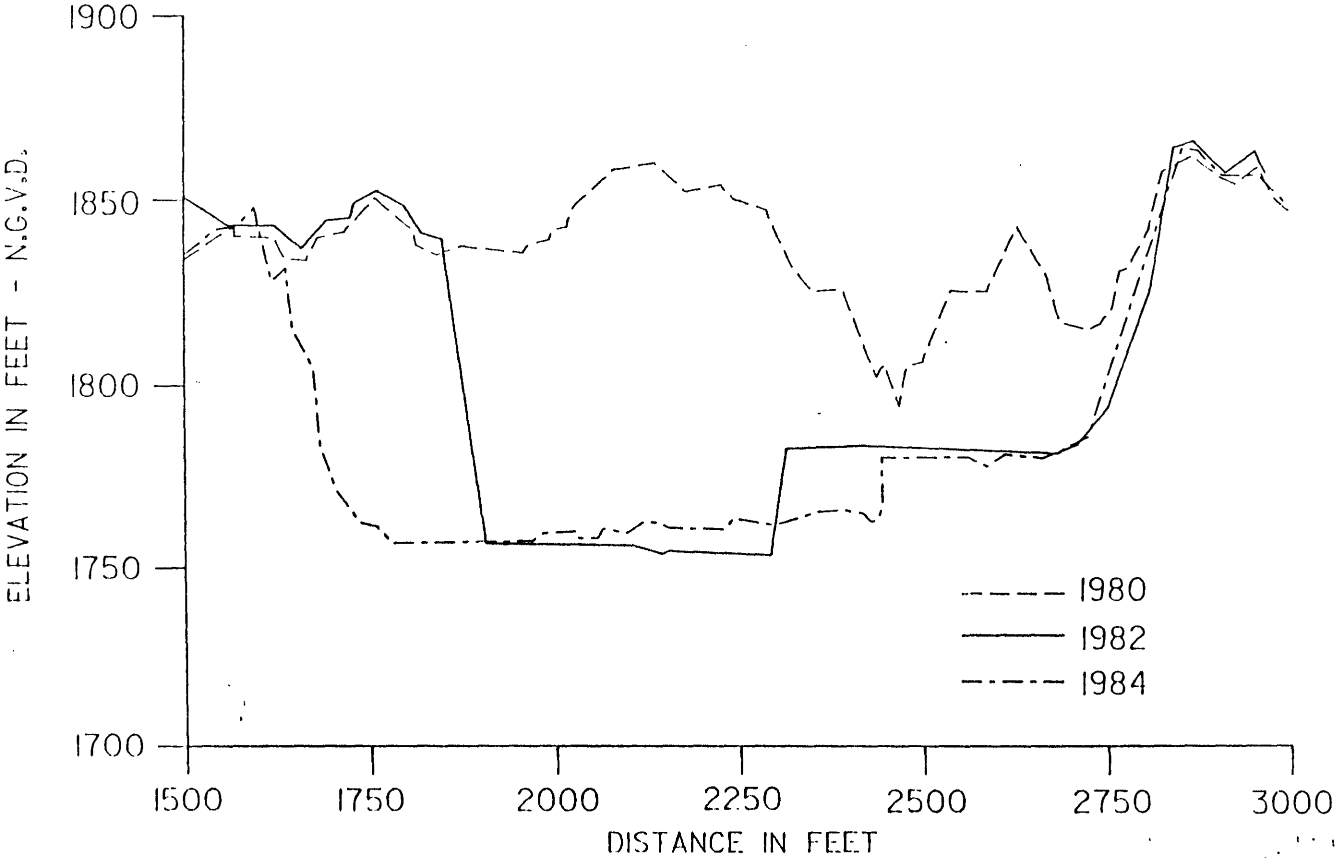


FIGURE A-6: CROSS SECTION 19-168

erosion from the Spirit Lake pumping operation. Much of the channel is armored to flow conditions that will greatly exceed post project conditions. As a result, sediment yields from this reach are expected to decrease dramatically from the pumping condition yields of 4-12 mcy/year to less than 1 mcy/year without pumping.

Coldwater Outlet to Elk Rock: The Coldwater to Elk Rock reach has evolved rapidly during the post eruption period. Initially, the Elk Rock area formed a large blockage in a narrow portion of the N. Fork Toutle River valley. This reach cut down rapidly through the blockage forming channel banks greater than 100 feet high. Incision has decreased dramatically since the end of the 1982 water year. Since that time, bank widening has been the predominant source of sediment. Figure A-6 shows the development of a representative cross section from the Elk Rock blockage area during the past eruptive period. Erosion from this reach has averaged nearly 8 mcy/year.

Post Spirit Lake diversion tunnel discharge should continue to destabilize this reach. High discharges of sediment free water should cause rapid bank and bed erosion. It is projected that bank erosion will be the predominant source of sediment in the future. Bank erosion should continue until all of the available debris avalanche deposit is removed above the present bed of the North Fork Toutle River, leaving behind a residue of coarse gravels and cobbles. Sediment yields are expected to decline from 8 mcy during the 1986 water year to less than 1 mcy/year by water year 2000 for a total of 60 mcy.

Once the stream has worked its way across the valley (in 15 to 20 years), the erosion rates will be similar to those observed in other reworked fluvial reaches of the avalanche.

Reworked Fluvial Sediments: This reach consists of approximately 60 mcy of reworked fluvial sediments from the N-1 debris retention structure to the Coldwater outlet. As the Elk Rock blockage is eroded and sediment is preferentially transported, the volume of the reworked fluvium is expected to increase to approximately 100 mcy. It is expected that as sediment yields are reduced from the upstream reaches, that this reach will change from a sediment

sink to a sediment source. The fluvial deposits will not be eroded and transported as rapidly as the avalanche deposits since they are somewhat coarser. A grain size stability analysis indicates, however, that the partical sizes found in the bed of the river are substantially less than those required for channel armoring at high discharges. The channel may continue to switch back and forth between the North Fork channel on the south side of the valley, Bear Creek channel on the north, and between the two channels through the center of the valley. Projected sediment yields from the fluvial deposits are expected to be 1 mcy/year through the next 50 years leaving a coarse residuum of gravel, cobbles, and boulders.

Forecast Conclusions, Base Sediment Budget

Table A-3 summarizes the forecasted sediment yields from the reaches of the debris avalanche discussed above. The values shown in Table A-3 are intended to show the relative significance of the various reaches and the yield decay which is expected to occur over time. Variability in hydrologic and volcanic events is expected to cause variations from the sediment yields shown on Table A-3 on both a year-by-year and a reach-by-reach basis. Figure A-7 shows the projected sediment yields from the debris avalanche. In general, the forecasted sediment budget, as presented, is a mudflow dominated budget. The Elk Rock reach is the only area where significant quantities of sediment yield are expected that are not directly or indirectly related to mudflows.

TABLE A-3

FORECAST EROSION FROM THE DEBRIS AVALANCHE

(mcy/year)

	1986	1995	2010	2035	TOTAL
Hillslope	0	0	0	0	0
Mt. St. Helens	2	2	2	2	100
Pumice Pond, Loowit	5	5	4	4	225
Carbonate, Coldwater					
Castle Creek	2	0	0	0	8
Spirit Lake-	<1	0	0	0	0
Coldwater Outlet					
Coldwater Outlet-	8	2	0	0	60
Elk Rock					
Reworked Fluvium	1	1	1	1	50
Total of Above	18	10	7	7	443 1/

1/ Rounded to 440 mcy

Recommended Forecast, 550 MCY Sediment Budget

In May, 1985 there was a second meeting of the Sediment Advisory Group at which the Portland District presented the 440 mcy forecast. That review resulted in a recommendation that an additional 25%- 50% should be added to the forecast.(See Exhibit A-2 for the consultants' comments on that meeting.) Following is the rationale for the addition:

"1. We have carefully reviewed the quantities and over-all results of the District's analysis and consider that a degree of conservatism is warranted in the estimate of avalanche yield over 50 years for the following reasons:

a. Even though the monitoring has been at a high quality and quantity level, hydrologic events during the 5 years since the eruption have not yielded a good sampling of what can occur in the future.

b. Modeling studies since our last meeting indicate that much more incision into the avalanche can occur than was previously considered.

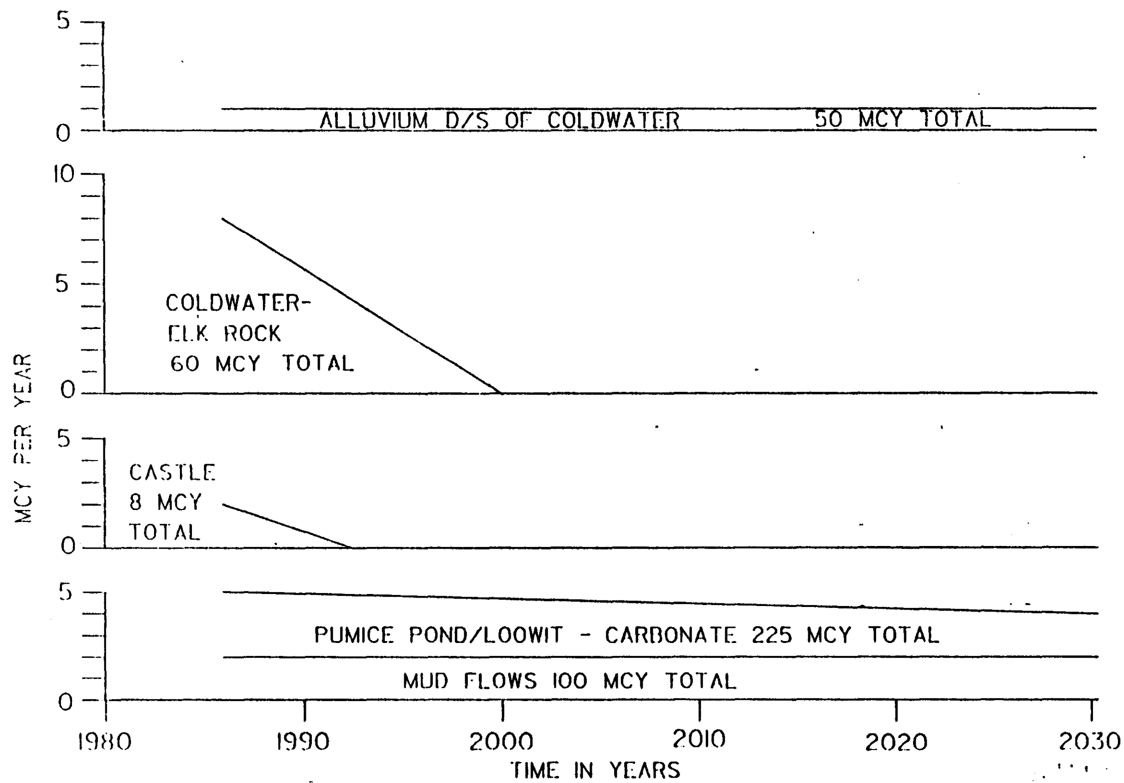


FIGURE A-7: PROJECTED 50 YEAR EROSION (440 BUDGET)

c. The possible sequences of channel degradation, widening, and migration within the avalanche area are many and are difficult to predict. Such changes can greatly influence the rate by which erosion decreases with time.

2. As a consequence of this concern, the consultants suggest that the 50-year sediment yield of 440 mcy may be increased by 25 to 50 percent.

3. The primary change is an increase in the erosion downstream of Coldwater Creek because of the increased ability to incise as demonstrated by the model, and availability of material. The suggested yield increase depletes a total of only 15 percent of the avalanche material in 50 years, including 25 percent of the material in the Elk Rock-Coldwater reach."

As a result, the Portland District, in a joint review meeting with the North Pacific Division and the Office of the Chief Engineers, agreed that the expert opinions were valid and that the base estimates should be adjustment. For the reasons cited by NPD and WES representatives concerning potential avalanche erosion due to low-frequency hydrologic events and the reasons given in the consultants report, the Corps of Engineers increased the base budget from 440 mcy to 550 mcy. The current sediment budget has an initial sediment yield of 23 mcy/year and a total yield of 550 mcy over the period of water year 1986-2035.

Erosion and Deposition Downstream from the Debris Avalanche

Changes in volumes of sediment transport and deposition continue below the debris avalanche. There are 37 RMs between the terminus of the debris avalanche and the confluence of the Toutle River with the Cowlitz River. Within this reach nearly 10 mcy of material have eroded and millions more could potentially erode. Since WY 1981 the North Fork and main stem of the Toutle River have responded in much the same way as the debris avalanche, with general channel aggradation and bank erosion. Repeated cross-sections surveyed by the USGS and COE were used to determine sources and quantities of erosion on the lower 37 miles of the North Fork Toutle and Toutle rivers. Table A-4 shows the results of the cross section data.

TABLE A-4

NORTH FORK AND TOUTLE RIVER SEDIMENT YIELDS

WATER YEAR 1981-84

AVE. END AREA METHOD

REACH	YIELDS (MCY)
N1 - KID VALLEY	-4.3 (DEPOSITION)
NF1	2.9
LT3	3.5
LT1	3.2
NET TOTAL EROSION	5.3
GROSS TOTAL EROSION	9.6

As can be seen in Table A-4, the North Fork and the Main Stem Toutle Rivers downstream of the Kid Valley area are a significant source of sediment during the post eruptive period.

Erosion Forecast

Most of the measured erosion downstream of the debris avalanche occured from 1981-1983. The process of bank erosion is self limiting. As a result it is expected that erosion rates will diminish rapidly with time. Forecasted erosion is 2,1,1, and 0 mcy per year for water years 1986, 1987, 1988 and 1989 respectively.

SEDIMENT DEPOSITION FORECAST

Introduction

The following is a discussion of the sediment deposition forecast for the Cowlitz and Columbia rivers over the next 50 years. The methods used to develop the forecasts, the critical elements involved in the forecast, and the impacts of deposition on Cowlitz River flood heights and the Columbia River are discussed.

Cowlitz River

Cowlitz River deposition is dependent on the volume and gradation of sediment delivered by the Toutle River and on the Cowlitz River's own sediment transport capability. The predicted sediment erosion was discussed in detail earlier. However a final adjustment in sediment delivery volumes is described in this section. An evaluation of the Cowlitz River's transport capability and depositional characteristics, based on observed data, is also described in this section.

Toutle River Sediment Delivery

The sediment yield from the Toutle basin, espressed in terms of expected volume of erosion, was presented previously. However, since volume is related to the inplace volume of the material, there is a significant increase between a given volume of erosion and the resulting volume of deposition. The increase in volume is caused by a reduction in unit weight between the original avalanche deposit and the resulting alluvial deposit. In this case, the average unit weight of the debris avalanche was estimated to be 110 lb/ft^3, while the Cowlitz River deposits have an estimated average unit weight of 95 lb/ft^3. When this reduction in unit weight is accounted for, it results in a 16% increase in volume. The impact this has on the Toutle River sediment delivery is shown on Figure A-8.

The particle size of future Toutle River sediment discharges is assumed to be similiar to those observed since the eruption for this forecast. Table A-5 lists the average size class percentages for the total sediment discharge during WY 1982 through WY 1984. This estimate was based on Toutle River suspended-sediment measurements taken at Tower Road and on bed material gradations taken downstream of Tower Road in both the Cowlitz and Toutle rivers. The grain size distribution listed in Table A-5 was assumed to be the distribution throughout the forecast period.

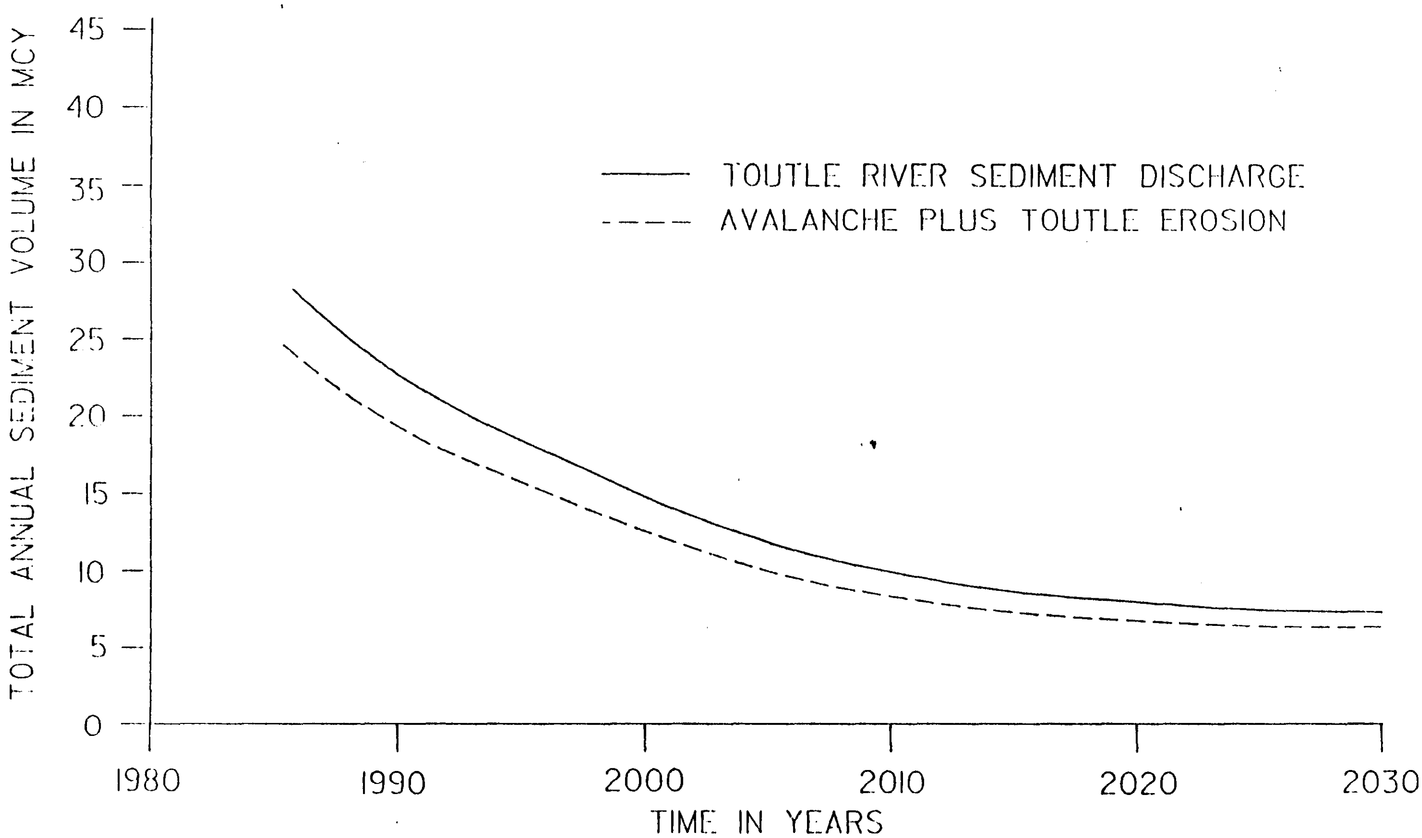


FIGURE A-8: TOUTLE RIVER EROSION/YIELD FORECAST (440 BUDGET)

TABLE A-5

TOUTLE RIVER SEDIMENT DISCHARGE, GRAIN SIZE DISTRIBUTION

Size Class	Percentage of Total
Silt/Clay	42
Very Fine Sand	17
Fine Sand	20
Medium Sand	11
Coarse Sand	5
Very Coarse Sand and Gravel	5

Cowlitz River Sediment Transport

For purposes of this study, it was necessary to estimate the average annual sediment transport capacity of the Cowlitz River. This capacity is influenced by individual storm events in all seasons, but is most dependent on the conditions during the November through March flood season. Streamflows during that time vary greatly, but follow a similiar pattern from year to year. It was, therefore, assumed that the average annual transport capacity remains constant for any combination of flow conditions which aggregate to average conditions.

The COE and USGS monitoring programs on the Cowlitz and Toutle rivers have provided an excellent data base from which to analyze transport capacity. This data base includes Toutle and Cowlitz river streamflow and suspended-sediment measurements, Toutle and Cowlitz rivers dredging volumes, Cowlitz River deposition volumes, grain size information, and stream profiles. Because of the quality and quantity of available data and the limitations of past sediment transport modeling (SS/84) it was decided to use only the observed data to estimate the average annual transport capacity.

The annual transport rate of the Cowlitz River was determined from mass balance calculations for each of the 3 years from WY 1982 through WY 1984. In

those calculations the volume of deposition in the Cowlitz River and at LT-1 was subtracted from the total sediment inflow to arrive at the amount of sediment transport. The deposition that occurred in the sump at the mouth of the Cowlitz river was excluded in these calculations since that material was deposited because of the sump. Because grain size is an important factor in sediment transport, the above calculations were done for selected grain sizes.

The results of the mass balance calculations are shown on Table A-6. The annual rates show some variation, but the individual grain sizes exhibit consistent trends. Silts and clays make up an insignificant portion of the Cowlitz River's bed, indicating that the Cowlitz has transported essentially all these materials received from the Toutle River. Silts and clays can therefore be considered wash load and are not expected to deposit in the future. Sand sizes from very fine up to coarse are generally transported as suspended-sediment by both the Toutle and Cowlitz rivers. However, in the Cowlitz River these sizes are selectively deposited as the transport rate varies greatly between sizes. Most of the very fine sand reaching the Cowlitz is transported through, while all of the coarse sands are deposited. Very coarse sand and gravels are transported as bedload by the Toutle and move only a few miles in the Cowlitz River before they are all deposited.

TABLE A-6

COWLITZ RIVER SEDIMENT INFLOW AND OUTFLOW

FOR WATER YEARS 1982 THROUGH 1984 IN MCY

Size	WY 1982		WY 1983		WY 1984	
Class	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
Silt/Clay	16.1	16.0	13.7	13.6	7.7	7.6
Very Fine Sand	6.6	5.9	5.7	5.2	3.0	2.8
Fine Sand	6.2	3.2	7.2	5.0	4.6	3.2
Medium Sand	3.1	0	3.8	1.1	3.2	1.0
Coarse Sand	1.8	0	1.5	0	1.3	0
Very Coarse Sand and Gravel	1.6	0	1.0	0	1.7	0

The sediment inflows and Cowlitz River discharges during WY 1984 were the closest of the 3 years to the expected initial average annual conditions of the 440 mcy base estimate. Water year 1984 therefore provided the basis for estimating the Cowltiz River's average annual transport potential (Table A-7). The observed WY 1984 rates were used for all sizes except very fine sand. Based on the higher transport rates of very fine sand observed in WY's 1982 and 1983, and of fine sand in WY 1984, the potential for very fine sand was raised from 2.8 mcy/yr observed in WY 1984 to 3.5 mcy/yr.

TABLE A-7

AVERAGE ANNUAL COWLITZ RIVER SEDIMENT TRANSPORT IN MCY

Size Class	Annual Transport mcy
Silt/Clay	10+
Very Fine Sand	3.5
Fine Sand	3.2
Medium Sand	1.0
Coarse Sand	0
Very Coarse Sand and Gravel	0

Cowlitz River Deposition

The two important elements of Cowlitz River deposition are the volume and the distribution. Each of these are discussed in the following paragraphs.

The volume of sediment forecast to deposit annually in the Cowlitz River over the next 50 years is shown in Figure A-9. That deposition was predicted by subtracting the average annual Cowlitz River transport potential from each of the predicted annual Toutle River sediment discharges. As Figure A-9 shows, deposition is expected to continue through the entire 50-year period. This is caused by the continuous deposition of all the coarse sand and larger

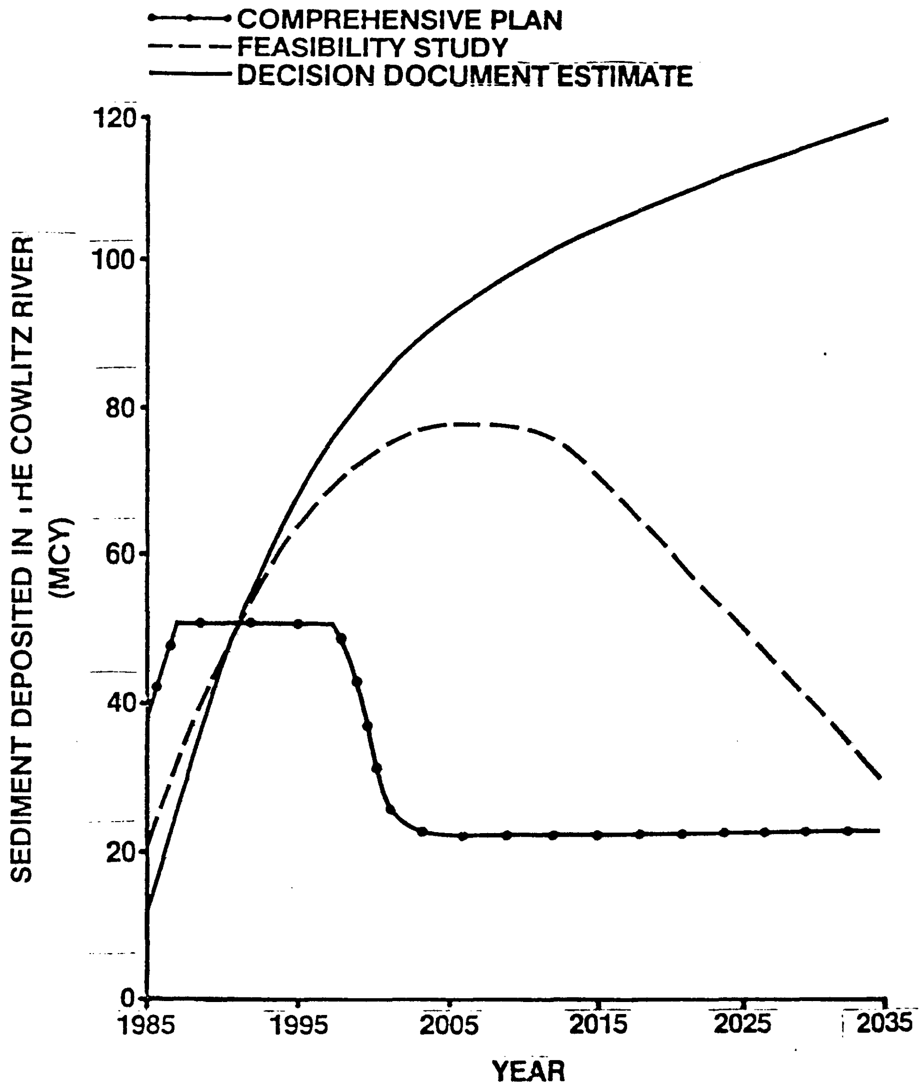


FIGURE A-9: COWLITZ RIVER DEPOSITION FORECAST

sediments in that reach of the Cowlitz River. The total deposition forecast to occur over the next 50 years is nearly 110 mcy, with 60% of the total being coarse sand and larger sediment.

The distribution of sediment within the Cowlitz River is needed to fully identify the potential damages. That distribution was extrapolated from current depositional patterns. Figures A-10 and A-11 show the deposition patterns for two reaches, RMs 0 to 10 and RMs 10 to 20, covering the Cowlitz River downstream of the Toutle confluence. Since October 1982, 80% of the net deposition in the Cowlitz River has occured upstream of RM 10, with only 20% downstream of that point. This depositional pattern is expected to continue in the future. The coarse sands and gravels are expected to continue to deposit upstream of RM 10 throughout the 50-year period. As bed levels in the channel rise, more and more sediment will be deposited in the floodplain. As the channel fills, the Cowlitz upstream of RM 10 will become very unstable and could begin to meander outside the current channel limits. Downstream in the Longview area the bed materials will be finer than near Castle Rock. Downstream of RM 10 deposition will be at a slower rate than in the upstream reach, but will also continue for 50 years. In this reach the Cowltiz channel should be maintained in its present alignment by the levee systems.

Cowlitz River Flood Profiles

Sediment deposition in the Cowlitz River causes an increase in potential flood heights and a corresponding decline in the level of protection for the communities of Longview, Kelso, Lexington and Castle Rock. Future flood heights are based on the amount of deposition expected in a reach and the observed relationship between flood heights and deposition within the reach. The flood height versus deposition relationships were determined by plotting the computed flood heights against the sediment volume in the appropriate reach, for each Cowlitz River survey since October 1981.

In addition to the annual deposition, each of the storms for which flood profiles were calculated added an increment to the volume deposited in the Cowlitz River. This increment is dependent on the design sand yield for each

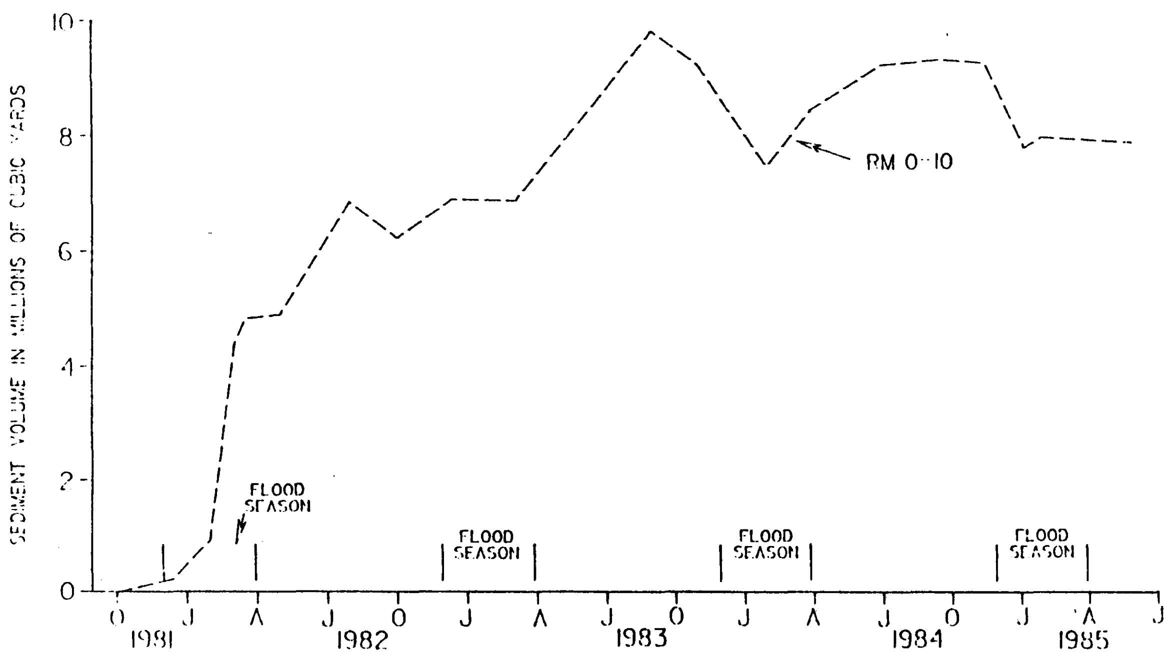


FIGURE A-10: OBSERVED COWLITZ RIVER DEPOSITION BETWEEN RM RM'S 0 AND 10 SINCE OCTOBER 1981

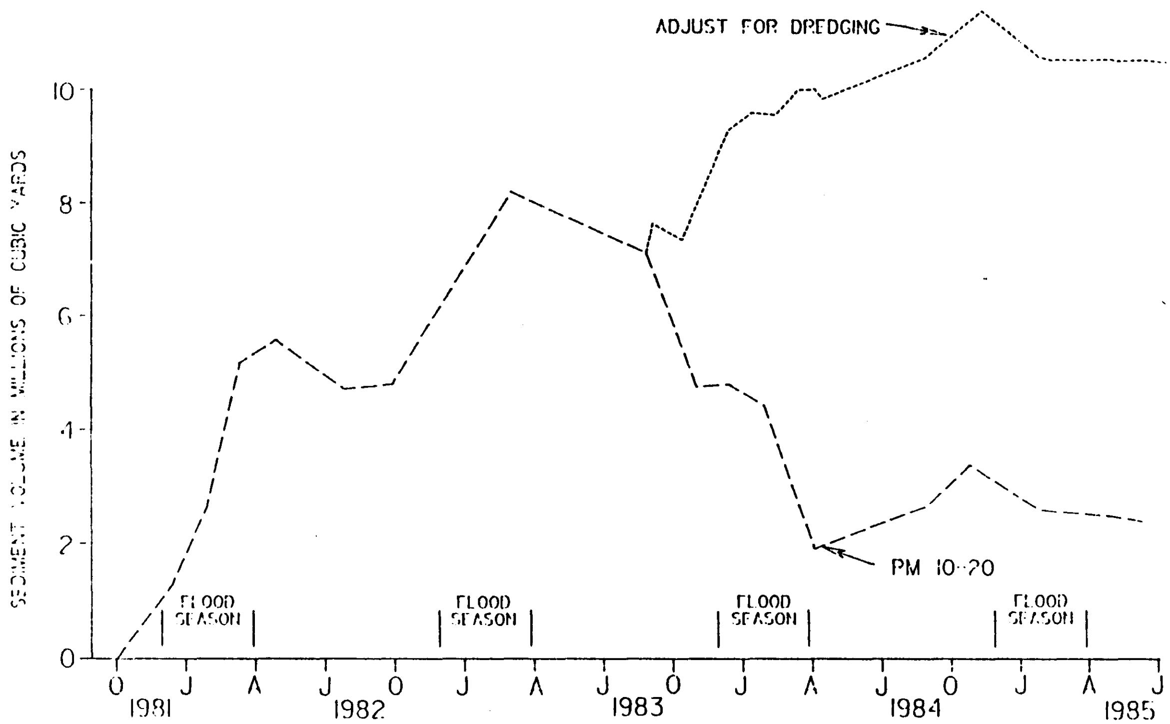


FIGURE A-11: OBSERVED COWLITZ RIVER DEPOSITION
BETWEEN RM'S 10 AND 20 SINCE OCTOBER 1981

storm and is the amount expected to deposit prior to the flood peak. This concept is explained in the Comprehensive Plan and in the Cowlitz and Toutle Rivers Sedimentation Study 1980-1982. The sediment loads expected to occur during each of the storms are the same as those in SS/84; however, the expected deposition has been increased. This increase is the result of an analysis of observed deposition during WY's 1983 and 1984. The design sand yield and resulting deposition are shown in Table A-8.

TABLE A-8

DESIGN SAND YIELD AND DEPOSITION DURING "RISING SIDE" OF HYDROGRAPH FOR MAJOR FLOODS

Average Exceedence Interval	Design Sand Yield to Cowlitz (mcy)	Deposition in Cowlitz (mcy)
10	4.0	1.9
50	6.0	2.6
100	7.0	3.0
500	12.0	5.4

Figures A-12 and A-13 show the predicted flood elevation changes over time at RMs 5.5 and 17.6. These curves account for each of the factors discussed above. The curves are based on observed relationships between streamflow, sediment load, and deposition. Extrapolation beyond the observed range of data was necessary in many cases, due to the magnitude of the sediment problem.

Columbia River

This sediment deposition forecast for the Columbia River primarily addresses deposition which would affect the navigation channel and increase maintainance dredging costs. Deposition adjacent to the navigation channel is included to a limited degree, but side-channel, backwater, and estuarine deposition are not included.

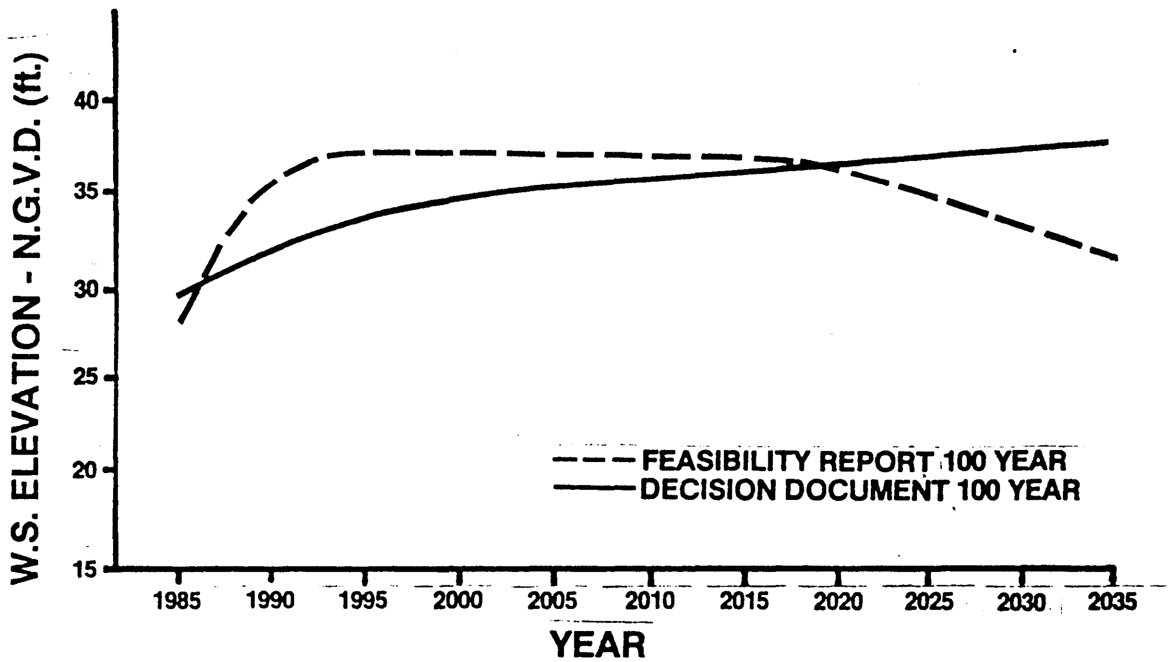


FIGURE A-12: 100-YEAR FLOOD ELEVATIONS AT COWLITZ RM 5.5

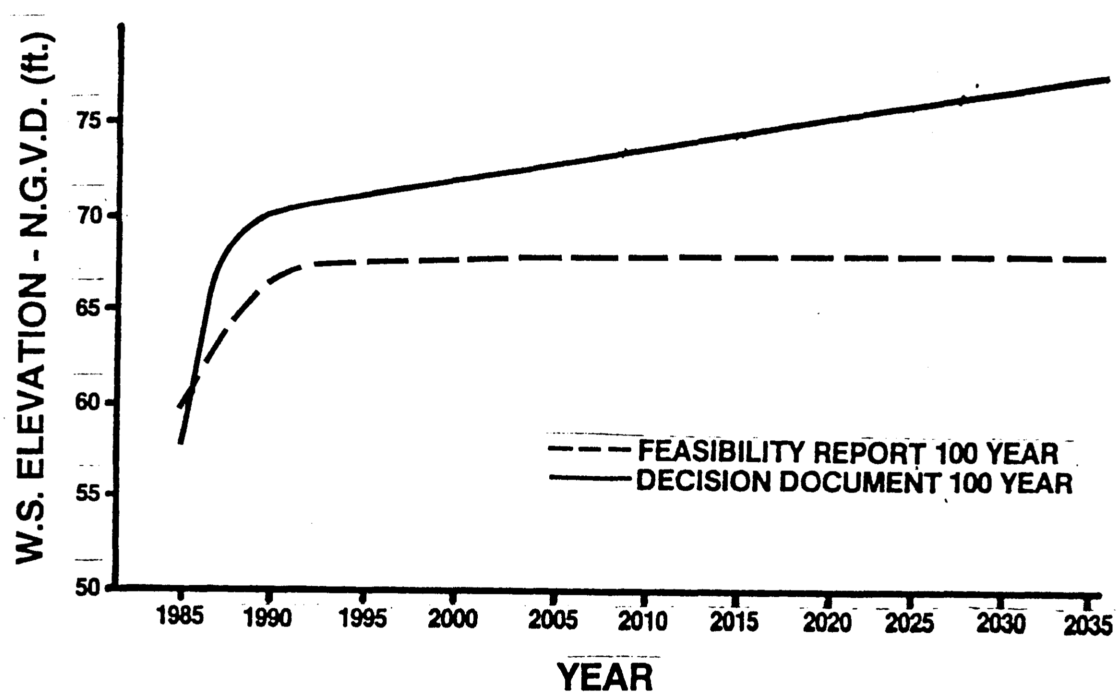


FIGURE A-13: 100-YEAR FLOOD ELEVATIONS AT COWLITZ RM 17.6

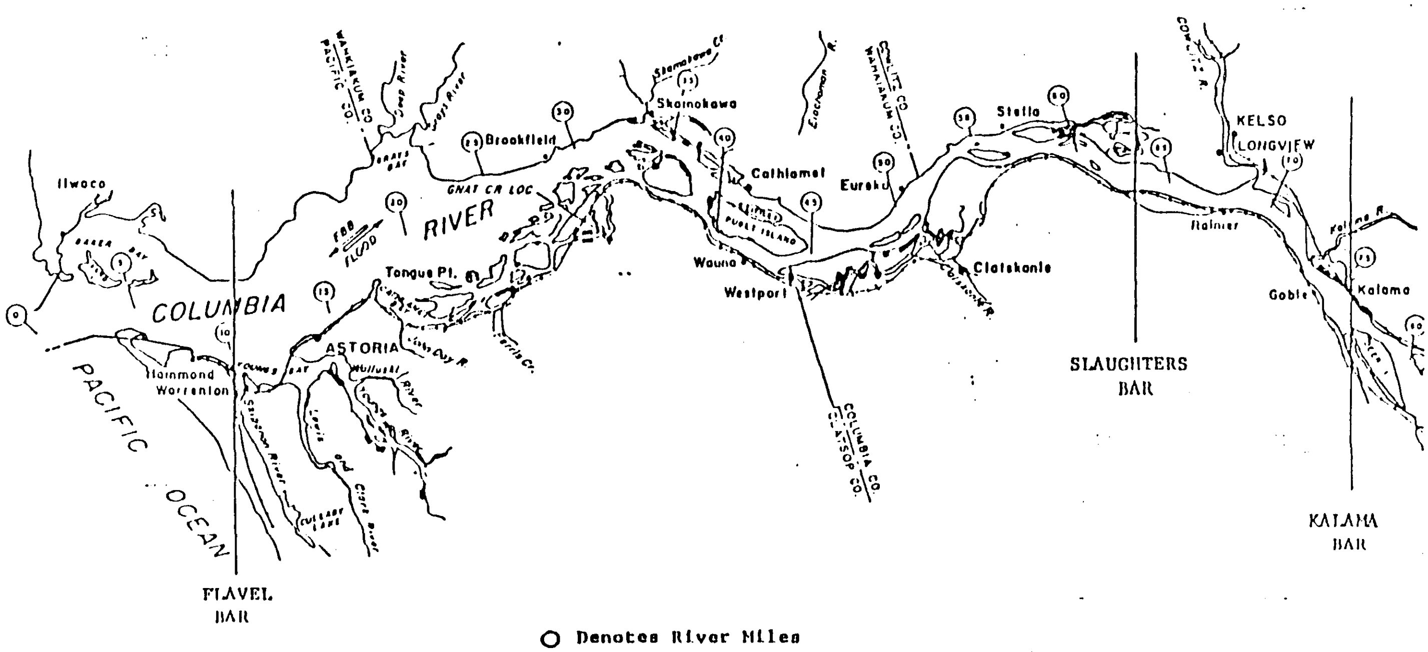
The sediment transport processes of the Columbia River are not well understood. The lack of historic data and the highly variable seasonal flow characteristics of the Columbia make the analysis of sediment transport all the more difficult. Two analyses of observed data were used to arrive at this deposition forecast. The first was a general aggradation/degradation evaluation between Rm 11 and RM 76 to identify potential depositional problems. The second was a more detailed analysis of Lower Dobelbower Bar, which was identified in the general evaluation as a potential problem.

Columbia River RM 11 to RM 76: An evaluation of aggradation/ degradation trends in the Columbia River between RM 11 and RM 76 was presented in the Columbia River Shoaling Study (COE, 1985). This evaluation used annual hydrographic surveys and dredging records to determine the naturally occurring changes in sediment volume along the main river channel since the 1980 eruption. The significant findings of this evaluation are:

1. All bars except Walker Island (Figure A-14) showed significant aggradation at some point following the eruption. This was most immediate and dramatic near the Cowltiz confluence. The aggradation was less pronounced and appears to have lagged up to a year in the downstream reaches.

2. Most bars have subsequently shown a degradation trend toward recovery from the initial eruption caused deposition.

3. Only three bars showed an increase of 1 mcy or more in sediment volume over the 1982 and 1983 water years, while five bars showed reductions of that magnitude (table A-9).



O Denotes River Miles

FIGURE A-14: AREA MAP OF COLUMBIA RIVER BARS

TABLE A-9

POST ERUPTION TRENDS IN

AGGRADATION/DEGRADATION

OF COLUMBIA RIVER REACHES

Bar Name	Significant Aggradation	Near Equilibrium	Significant Degradation
Kalama		X	
Upper Dobelbower		X	
Lower Dobelbower	X		
Slaughters		X	
Walker Island		X	
Stella Fisher		X	
Gull Island	X		
Eureka	X		
Westport		X	
Wauna-Driscoll		X	
Puget Island		X	
Skamokawa			X
Brookfield-Welch			X
Pillar Rock			X
Miller Sands		X	
Tongue Pt. Crossing			X
Flavel			X

Significant aggradation or degradation is arbitrarily defined as that which exceeds 1 mcy over the 1983 and 1984 hydrographic surveys.

The above findings indicate that during a two year period, when over 14 mcy of sand were discharged into the Columbia River, there were only three bars which experienced over 1 mcy of aggradation. Of those three, only Lower Dobelbower is a factor in this forecast, as the other two have required only minor amounts of dredging.

Lower Dobelbower Bar: Lower Dobelbower Bar is located between RM's 67 and 70 and includes the Cowlitz River confluence. In reviewing the deposition which has occurred in this reach there were two factors which seemed to be of over-riding importance; the location of deposition and the gradation of the sediments.

The annual deposition identified in the general evaluation was predominately located upstream of the mouth of the Cowlitz River. Because this reach of the Columbia River does not experience flow reversals, such as occur in the estuary, that location strongly suggests a sediment source in the Columbia, upstream of the Cowlitz River. Sediment gradations in this reach have varied only slightly since the eruption, indicating a common source, such as the 1980 mudflow. Sufficient data is not available to positively identify the current sediment source.

There was some deposition downstream of the Cowlitz River, particularly in December 1982 when deposition threatened to interfere with navigation. The December 1982 deposition corresponded with a large storm in the Toutle watershed and was originally thought to have been caused by Cowlitz River sediment discharges. An evaluation of the gradations of the depositon and sediment discharges indicated the Columbia deposits were noticably coarser than the suspended-sediment discharges. The Columbia deposits were also much coarser than the sediment deposited in the sump at the mouth of the Cowlitz River during the same December 1982 time period. This sump should have trapped coarse sediments if they were part of the Cowlitz River bedload. The gradation of the December 1982 Columbia deposits is very similiar to other bed gradations measured between Columbia River Miles 66 and 72 since the 1980 eruption. The consistently coarser gradation of Columbia bed material as compared to the Cowlitz River sediment discharges, indicate the Cowlitz is not a significant factor in Lower Dobelbower Bar deposition.

Deposition Forecast: As indicated by the previous two sections, there has not been a significant increase in overall Columbia River deposition since the 1980 eruption. Some increase was observed near the Cowlitz/Columbia confluence but the available data suggests some cause other than the

post-eruption Cowlitz River sediment discharges. Therefore no significant increase in Columbia River deposition due to the avalanche erosion is anticipated to occur over the next 50 years. The depositional processes are not well defined and extreme flood events or mudflows could cause unforeseen deposition.

CONCLUSIONS

Geomorphic processes occuring in the debris avalanche stream channels are causing a gradual decline in erosion rates. This forecast predicts the erosion rates will decline from the current 18-23 mcy/yr range to about 13 mcy/yr by the turn of the century and to nearly 6 mcy/yr in 50 years. The total erosion during the next 50 years is expected to be 550 mcy. These high yields are due to the abundant supply of water including extreme storm event sediment and the long-term destabilizing impacts of volcanic caused mudflows. As erosion rates decline, the estimates of deposition in the Cowlitz River fall from 9 mcy in WY 1986 to 2 mcy in WY 2000 and to 1 mcy in WY 2035. The expected long-term deposition is more severe than earlier estimates with a 50 year total of 110 mcy, due to the continuous delivery of coarse sands and gravels. Those classes make up only 10% of the expected sediment yields, but cause 60% of the expected Cowlitz River deposition. Conversely, Columbia River deposition is expected to be insignificant because of the deposition of coarse sediment in the Cowlitz River and the inability of the Cowlitz River to move this coarse material.

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CONSULTANTS' COMMENTS

ON

TOUTLE AND COWLITZ RIVERS SEDIMENT ANALYSIS

May 24, 1985

The consultants consider that the NPP staff has responded effectively to our comments at the March 1985 meeting and have performed a highly professional analysis of probable future sediment erosion, transport, and deposition.

Sediment Yield Curve

1. We have carefully reviewed the quantities and over-all results of the District's analysis and consider that a degree of conservatism is warranted in the estimate of avalanche yield over 50 years for the following reasons:

   a. Even though the monitoring has been at a high quality and quantity level, hydrologic events during the 5 years since the eruption have not yielded a good sampling of what can occur in the future.

   b. Modeling studies since our last meeting indicate that much more incision into the avalanche can occur than was previously considred.

   c. The possible sequences of channel degradation, widening and migration within the avalanche area are many and are difficult to predict. Such changes can greatly influence the rate by which erosion decreases with time.

2. As a consequence of this concern, the concultants suggest that the 50-year sediment yield of 440 mcy may be increased by 25 to 50 percent.

3. The primary change is an increase in the erosion downstream of Coldwater Creek because of the increased ability to incise as demonstrated by the model, and availability of material. The suggested yield increase depletes a total of only 15 percent of the avalanche material in 50 years, including 25 percent of the material in the Elk Rock-Coldwater reach.

Toutle River Gravels

1. Accumulation of gravels in Toutle River:

a. The avalanche sediments contain modest amounts of gravel. Sediment in the gravel sizes has been trapped in bedload samplers by the U. S. Geological Survey personnel in the Toutle River, showing that such materials are moved even under modest flows. The transport rate of gravels in the Toutle River is expected to be low. However, further investigations should be undertaken to determine if gravel deposits pose problems in the river.

b. These investigations should start with the review of size distribution of samples of bed sediment in the Toutle River to determine the amount of gravel present. It is of interest to determine whether such sediment derives from the bank or is brought in by the flows.

c. Another part of the investigation is to determine the competence of the flows to move sediment of various sizes. To do this, the bed shear stresses at various stations along the river should be determined for various expected flows. These stresses should be compared with the Shields shear stresses for the several sizes of gravel to determine if they will be moved by the flows. This would give an indication of what grain sizes would move in the various reaches of the river.

d. As bedload samples become available, they should be analyzed to determine rates of movement of gravel.

2. The above investigations should indicate if accumulations of gravel will form and if they pose problems.

Analysis of Present and Future Sediment Problems in the Cowlitz River

1. The analysis of the Cowlitz system downstream of the Toutle River has been reviewed utilizing:

a. Data base
b. Dredging requirements.
c. Hydraulic conditions.
d. Observed responses of the system.
e. HEC 2 and HEC 6 modeling.

2. The analysis has resulted in an adequate understanding of the physical processes active in the system and the system's response to these processes.

3. The conclusions of the Consultants to the present analysis are:

a. Within the first five-mile reach downstream of the confluence, it is anticipated that aggradation caused by overloading the river with coarse sand and some gravel will require periodic dredging.

The quantities that should be dredged are highly dependent upon sediment control measures implemented in the Toutle River and climatic and hydrologic conditions in the watershed.

b. Assuming implementation of adequate sediment control measures in the Toutle River, it is concluded that no significant sediment problems should develop in the remainder of the Cowlitz River or in the Columbia River unless impaired by major flood and related episodic events.

Leo R. Beard	June 20, 1985 Date
Daryl Simons	June 18, 1985 Date
Vito A. Vanoni	June 13, 1985 Date

APPENDIX B

MEASURE COST SUMMARY

APPENDIX B

MEASURE COST SUMMARY

INTRODUCTION

Purpose

This appendix contains cost data for each of the measures addressed in this document. The cost figures in tables B-1 and B-2 summarize the following information:

- °average annual and total cost for three levels of dredging on two rivers
- °the same costs for five spillway heights, two methods of construction on two rivers
- °the same costs for four staging options

Table B-3 provides average annual and total costs for levee improvements at Longview, Kelso, Lexington and Castle Rock. Table B-4 provides cost flows for the years 1986-2035 for the dredging plus minimal levees at Kelso, Lexington, and Castle Rock. Table B-5 provides annual volumes for base dredging. Table B-6 summarizes the total project cost. Table B-7 summarizes the cost flow for years 1986-2035 for the NED Plan - a 125-foot spillway SRS with greater than base dredging and a minimal levee improvement at Kelso. Table B-8 provides a summary of yearly dredging volumes fore base-plus dredging. Table B-9 provides the total SRS alternative project cost. Table B-10 summarizes the cost flow for years 1986-2035 for a 100-foot spillway MSRS to be raised to 125 feet, with greater than base dredging and a minimal levee at Kelso. Table B-11 provides the total project cost for this alternative. Table B-12 summarizes yearly dredging volumes for intermediate dredging.

Chart B-1 indicates sediment volume passed or dredged for three levees of dredging and the total average annual costs for the required dredging. Charts

B-2 and B-3 provide total and average annual costs for the dredging options on Toutle and Cowlitz River respectively. Chart B-4 indicates these same costs for Toutle and Cowlitz dredging and a 1/2 E budget. Chart B-5 shows sediment volumes trapped, passed or dredged for five sizes of SRS. Chart B-6 provides costs for the five SRS sizes studied (Cowlitz River dredging). Chart B-7 breaks down the costs for the selected SRS (El. 940 foot spillway) into the major components for Cowlitz River dredging. Chart B-8 provides costs for the SRS sizes with Toutle River dredging. Chart B-9 provides costs for a 1/2 E budget and the SRS sizes studied (Cowlitz River dredging). Chart B-10 shows the effect that design for a 1 1/2 E budget and Toutle dredging would have on the cost for a SRS. Chart B-11 compares the cost flows for dredging and a SRS with spillway at El. 940. Chart B-12 provides costs for a MSRS with initial spillway height of 100 feet, later raised to 125 feet. Chart B-13 shows a component cost summary for the best dredging/levee alternative - base dredging and minimal levee improvements at Kelso, Lexington, and Castle Rock. Chart B-14 provides a component cost summary for the NED plan - an SRS with spillway elevation 940 feet with base-plus dredging and a minimal levee improvement at Kelso. Chart B-15 compares the cost flows for base dredging and levee improvement at Kelso, Lexington, and Castle Rock with cost flows for an SRS with spillway at El. 940, base-plus dredging, and levee improvement at Kelso.

DECISION DOCUMENT COST MATRIX

AVERAGE ANNUAL COST IN MILLIONS OF DOLLARS

BUDGET ANALYZED

	DREDGE 1/ LOCATION	½'E' BUDGET SPILLWAY HT. (FT) 50	85	100	125	150	'E' BUDGET SPILLWAY HT. (FT) 50	100	125	150	200	1½'E' BUDGET SPILLWAY HT. (FT) (100')	OPTIMUM FOR 'E' (125')	(150')
SRS														
EMBANKMENT	T	6.82	6.78	6.50	6.59	7.67	12.06	9.45	8.62	9.09	11.62	14.19	10.84	10.63
EMBANKMENT	C	6.45	6.36	6.17	6.30	7.29	11.79	8.76	8.15	8.70	11.25	18.47	11.90	10.40
RCC	T	7.01	7.63	7.56	7.87		12.09	10.35	9.86	10.24	13.32		12.06	
RCC	C	6.56	7.10	7.13	7.58		11.89	9.65	9.40	9.86	12.95		13.12	

		STAGING ALTERNATIVE I	II	III	IV
STAGED SRS					
EMBANKMENT	T	9.86	9.53	9.17	8.97
EMBANKMENT	C	9.16	8.98	8.61	8.45

		½'E' BUDGET	'E' BUDGET	1½'E' BUDGET
DREDGING				
BASE	T	3.89	13.08	19.00
BASE	C	3.38	13.90	
INTERMEDIATE	T	5.21	16.50	26.06
INTERMEDIATE	C	4.73	20.51	
MAXIMUM	T		22.08	
MAXIMUM	C		26.13	

NOTE 1/ T = EMPHASIS ON TOUTLE DREDGING
C = EMPHASIS ON COWLITZ DREDGING
2/ COSTS DO NOT INCLUDE LEVEE IMPROVEMENTS

TABLE B-1

DECISION DOCUMENT COST MATRIX

TOTAL COST IN MILLIONS OF DOLLARS

BUDGET ANALYZED

SRS

DREDGE 1/ LOCATION		½'E' BUDGET SPILLWAY HT. (FT) 50	85	100	125	150	'E' BUDGET SPILLWAY HT. (FT) 50	100	125	150	200	1½'E' BUDGET SPILLWAY HT. (FT) (100')	OPTIMUM FOR 'E' (125')	(150')
EMBANKMENT	T	179.64	176.20	160.99	131.48	113.87	318.76	239.23	206.34	184.18	169.88	356.13	276.04 [3]	248.48
EMBANKMENT	C	170.45	166.36	152.00	125.27	109.14	380.40	233.50	201.88	177.77	165.16	593.50	402.51 [3]	293.69
RCC	T	178.04	181.90	170.29	146.48		312.56	245.23	217.34	195.18	191.88		286.04 [3]	
RCC	C	164.45	170.36	160.00	140.27		374.40	239.3[illegible]	213.58	188.77	187.16		412.51 [3]	

STAGED SRS

		STAGING ALTERNATIVE I	II	III	IV
EMBANKMENT	T	245.23	232.31	210.33	206.67
EMBANKMENT	C	241.41	231.66	206.60	203.12

DREDGING

		½'E' BUDGET	'E' BUDGET	1½'E' BUDGET
BASE	T	148.21	346.64	526.59
BASE	C	140.28	475.32	
INTERMEDIATE	T	190.26	476.13	748.10
INTERMEDIATE	C	204.45	662.13	
MAXIMUM	T		668.98	
MAXIMUM	C		793.59	

NOTE 1/T = EMPHASIS ON TOUTLE DREDGING
C = EMPHASIS ON COWLITZ DREDGING
2/COSTS DO NOT INCLUDE LEVEE IMPROVEMENTS
REVISED 8/27/85 DELETED DIRTY WATER ADJUSTMENTS

TABLE B-2

TABLE B-3

LEVEE COSTS

(Average Annual)

($1,000)

Levee Option	Longview	Kelso	Lexington	Castle Rock
Minimal	$ 0	$ 140	$ 100	$ 30
Medium	2,270	1,390 1/	350	270
High	2,630	1,930 1/	520	380

LEVEE COSTS

(Total)

($1,000)

Levee Option	Longview	Kelso	Lexington	Castle Rock
Minimal	$ 0	$1,870	$ 1,340	$ 380
Medium	33,500	20,370 1/	5,200	4,000
High	38,800	28,270 1/	7,700	5,700

1/ Kelso medium and high levee raise costs include the minimal levee raise in-place in 1987.

TABLE B-4

COST FLOW ($M)

PLAN -- BASE DREDGING + LEVEE (KL,LX,CR)

	SRS					DREDGING			LEVEE			OTHER			
	CONST	MONITOR	RE	RELOC	MITIGAT	COST	RE	MIT	COST	RE	O&M	REVET	REHAB	MON	TOTA
1986	0.00	0.00	0.00	0.00	0.00	19.38	0.58	2.06	0.00	2.00	0.00	5.2[illegible]	0.10	1.80	31.18
1987	0.00	0.00	0.00	0.00	0.00	15.49	0.33	1.78	1.48	0.00	0.00	3.4[illegible]	0.10	1.00	23.58
1988	0.00	0.00	0.00	0.00	0.00	15.31	0.33	1.76	0.00	0.00	0.04	0.00	0.10	1.00	18.54
1989	0.00	0.00	0.00	0.00	0.00	14.79	0.32	1.70	0.00	0.00	0.04	0.00	0.10	1.00	17.95
1990	0.00	0.00	0.00	0.00	0.00	14.44	0.32	1.66	0.00	0.00	0.04	0.00	0.10	1.00	17.56
1991	0.00	0.00	0.00	0.00	0.00	13.92	0.32	1.60	0.00	0.00	0.04	0.00	0.10	1.00	16.98
1992	0.00	0.00	0.00	0.00	0.00	12.18	0.15	1.40	0.00	0.00	0.04	0.00	0.10	1.00	14.87
1993	0.00	0.00	0.00	0.00	0.00	9.92	0.12	1.14	0.00	0.00	0.04	0.00	0.10	1.00	12.
1994	0.00	0.00	0.00	0.00	0.00	9.33	0.16	1.06	0.00	0.00	0.04	0.00	0.10	1.00	11.69
1995	0.00	0.00	0.00	0.00	0.00	10.53	0.59	0.98	0.00	0.00	0.04	0.75	0.10	1.00	13.99
1996	0.00	0.00	0.00	0.00	0.00	9.67	0.54	0.90	0.00	0.00	0.04	0.00	0.10	1.00	12.25
1997	0.00	0.00	0.00	0.00	0.00	9.03	0.50	0.84	0.00	0.00	0.04	0.00	0.10	1.00	11.51
1998	0.00	0.00	0.00	0.00	0.00	8.17	0.46	0.76	0.00	0.00	0.04	0.00	0.10	1.00	10.53
1999	0.00	0.00	0.00	0.00	0.00	7.52	0.42	0.70	0.00	0.00	0.04	0.00	0.10	1.00	9.78
2000	0.00	0.00	0.00	0.00	0.00	6.01	0.36	0.51	0.00	0.00	0.04	0.00	0.20	1.00	8.11
2001	0.00	0.00	0.00	0.00	0.00	3.00	0.20	0.21	0.00	0.00	0.04	0.00	0.20	1.00	4.66
2002	0.00	0.00	0.00	0.00	0.00	2.71	0.18	0.19	0.00	0.00	0.04	0.00	0.20	1.00	4.32
2003	0.00	0.00	0.00	0.00	0.00	2.41	0.16	0.17	0.00	0.00	0.04	0.00	0.20	1.00	3.98
2004	0.00	0.00	0.00	0.00	0.00	2.41	0.16	0.17	0.00	0.00	0.04	0.00	0.20	1.00	3.98
2005	0.00	0.00	0.00	0.00	0.00	2.27	0.15	0.15	0.00	0.00	0.04	0.00	0.20	1.00	3.82
2006	0.00	0.00	0.00	0.00	0.00	2.14	0.14	0.15	0.00	0.00	0.04	0.00	0.20	1.00	3.67
2007	0.00	0.00	0.00	0.00	0.00	2.00	0.13	0.14	0.00	0.00	0.04	0.00	0.20	1.00	3.51
2008	0.00	0.00	0.00	0.00	0.00	2.16	0.12	0.13	0.00	0.00	0.04	0.00	0.20	1.00	3.65
2009	0.00	0.00	0.00	0.00	0.00	2.16	0.12	0.13	0.00	0.00	0.04	0.00	0.20	1.00	3.65
2010	0.00	0.00	0.00	0.00	0.00	1.83	0.10	0.11	0.00	0.00	0.04	0.00	0.20	1.00	3.28
2011	0.00	0.00	0.00	0.00	0.00	1.83	0.10	0.11	0.00	0.00	0.04	0.00	0.20	1.00	3.28
2012	0.00	0.00	0.00	0.00	0.00	1.66	0.09	0.10	0.00	0.00	0.04	0.00	0.20	1.00	3.10
2013	0.00	0.00	0.00	0.00	0.00	1.66	0.09	0.10	0.00	0.00	0.04	0.00	0.20	1.00	3.10
2014	0.00	0.00	0.00	0.00	0.00	1.80	0.09	0.10	0.00	0.00	0.04	0.00	0.20	1.00	3.23
2015	0.00	0.00	0.00	0.00	0.00	1.80	0.09	0.10	0.00	0.00	0.04	0.00	0.20	1.00	3.23
2016	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.20	1.00	3.04
2017	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.20	1.00	3.04
2018	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.20	1.00	3.04
2019	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.20	1.00	3.04
2020	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.14
2021	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.14
2022	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.14
2023	0.00	0.00	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.14
2024	0.00	0.00	0.00	0.00	0.00	2.09	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.61
2025	0.00	0.00	0.00	0.00	0.00	2.09	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.61
2026	0.00	0.00	0.00	0.00	0.00	2.09	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.61
2027	0.00	0.00	0.00	0.00	0.00	2.09	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.61
2028	0.00	0.00	0.00	0.00	0.00	2.09	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.61
2029	0.00	0.00	0.00	0.00	0.00	2.09	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.61
2030	0.00	0.00	0.00	0.00	0.00	2.09	0.09	0.09	0.00	0.00	0.04	0.00	0.30	1.00	3.61
2031	0.00	0.00	0.00	0.00	0.00	1.86	0.08	0.08	0.00	0.00	0.04	0.00	0.30	1.00	3.35
2032	0.00	0.00	0.00	0.00	0.00	1.86	0.08	0.08	0.00	0.00	0.04	0.00	0.30	1.00	3.35
2033	0.00	0.00	0.00	0.00	0.00	1.86	0.08	0.08	0.00	0.00	0.04	0.00	0.30	1.00	3.35
2034	0.00	0.00	0.00	0.00	0.00	1.86	0.08	0.08	0.00	0.00	0.04	0.00	0.30	1.00	3.35
2035	0.00	0.00	0.00	0.00	0.00	1.86	0.08	0.08	0.00	0.00	0.04	0.00	0.30	1.00	3.35
															352.10

TABLE B-5
BASE DREDGING- TOUTLE RIVER INITIATED

YEAR	TOUTLE SITES NF-1 MCY	LT-3 MCY	LT-1 MCY	SUBTOTAL MCY	COWLITZ SITES RM 10-20 MCY	RM 0-10 MCY	SUBTOTAL MCY	TOTAL MCY
1986	3.0	4.5	1.5	9.0	2.0	0.6	2.6	11.6
1987	3.0	4.5	1.4	8.9			0.0	8.9
1988	3.0	4.5	1.3	8.8			0.0	8.8
1989	3.0	4.5	1.0	8.5			0.0	8.5
1990	3.0	4.5	0.8	8.3			0.0	8.3
1991	3.0	4.5	0.5	8.0			0.0	8.0
1992	4.0		3.0	7.0			0.0	7.0
1993	3.0		2.7	5.7			0.0	5.7
1994	5.3			5.3			0.0	5.3
1995	4.9			4.9			0.0	4.9
1996	4.5			4.5			0.0	4.5
1997	4.2			4.2			0.0	4.2
1998	3.8			3.8			0.0	3.8
1999	3.5			3.5			0.0	3.5
2000	1.8			1.8	1.2	0.3	1.5	3.3
2001				0.0	1.6	0.5	2.1	2.1
2002				0.0	1.5	0.4	1.9	1.9
2003				0.0	1.4	0.3	1.7	1.7
2004				0.0	1.4	0.3	1.7	1.7
2005				0.0	1.3	0.3	1.6	1.6
2006				0.0	1.2	0.3	1.5	1.5
2007				0.0	1.1	0.3	1.4	1.4
2008				0.0	1.0	0.3	1.3	1.3
2009				0.0	1.0	0.3	1.3	1.3
2010				0.0	0.9	0.2	1.1	1.1
2011				0.0	0.9	0.2	1.1	1.1
2012				0.0	0.8	0.2	1.0	1.0
2013				0.0	0.8	0.2	1.0	1.0
2014				0.0	0.8	0.2	1.0	1.0
2015				0.0	0.8	0.2	1.0	1.0
2016				0.0	0.7	0.2	0.9	0.9
2017				0.0	0.7	0.2	0.9	0.9
2018				0.0	0.7	0.2	0.9	0.9
2019				0.0	0.7	0.2	0.9	0.9
2020				0.0	0.7	0.2	0.9	0.9
2021				0.0	0.7	0.2	0.9	0.9
2022				0.0	0.7	0.2	0.9	0.9
2023				0.0	0.7	0.2	0.9	0.9
2024				0.0	0.7	0.2	0.9	0.9
2025				0.0	0.7	0.2	0.9	0.9
2026				0.0	0.7	0.2	0.9	0.9
2027				0.0	0.7	0.2	0.9	0.9
2028				0.0	0.7	0.2	0.9	0.9
2029				0.0	0.7	0.2	0.9	0.9
2030				0.0	0.7	0.2	0.9	0.9
2031				0.0	0.6	0.2	0.8	0.8
2032				0.0	0.6	0.2	0.8	0.8
2033				0.0	0.6	0.2	0.8	0.8
2034				0.0	0.6	0.2	0.8	0.8
2035				0.0	0.6	0.2	0.8	0.8
	-------	-------	-------	-------	-------	-------	-------	-------
	53.0	27.0	12.2	92.2	33.2	9.1	42.3	134.5

TABLE B-6

TOTAL PROJECT COST

DREDGING-BASE CONDITION AND KL/LX/CR MINIMUM LEVEES

($000,000)

<u>Total Project Cost</u>

Dredging		276.29
Construction	244.47	
Real Estate	9.15	
Mitigation	22.67	
Levees		5.46
Construction	1.48	
Real Estate	2.06	
O&M	1.92	
Other		70.35
Disposal Site Rahab.	10.20	
Revetments	9.35	
D/S Monitoring	50.80	
TOTAL PROJECT COST		352.10

TABLE B-7

COST FLOW ($M)
PLAN -- SRS + DREDGING + LEVEE(KL)
(WITH INTERMEDIATE DREDGING)

	SRS					DREDGING			LEVEE			OTHER			
	COST	MONITOR	RE	RELOC	MITIGAT	COST	RE	MIT	COST	RE	O&M	REVET	REHAB	MON	TOTA
1986	6.00	0.00	12.20	0.40	1.30	25.38	1.78	1.69	0.00	1.10	0.00	0.00	0.10	1.80	51.75
1987	17.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.00	17.84
1988	31.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	31.52
1989	9.70	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	9.82
1990	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1991	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1992	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1993	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1994	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1995	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1996	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1997	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1998	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1999	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
2000	0.10	0.10	0.00	0.00	0.00	2.84	0.17	0.18	0.00	0.00	0.02	0.00	0.10	1.00	4.51
2001	0.10	0.10	0.00	0.00	0.00	2.84	0.17	0.18	0.00	0.00	0.02	0.00	0.10	1.00	4.51
2002	0.10	0.10	0.00	0.00	0.00	2.87	0.15	0.16	0.00	0.00	0.02	0.00	0.10	1.00	4.49
2003	0.10	0.10	0.00	0.00	0.00	2.36	0.12	0.13	0.00	0.00	0.02	0.00	0.10	1.00	3.93
2004	0.10	0.10	0.00	0.00	0.00	2.36	0.12	0.13	0.00	0.00	0.02	0.00	0.10	1.00	3.93
2005	2.00	0.10	0.00	0.00	0.00	2.14	0.11	0.12	0.00	0.00	0.02	0.00	0.10	1.00	5.59
2006	0.10	0.10	0.00	0.00	0.00	1.97	0.10	0.11	0.00	0.00	0.02	0.00	0.10	1.00	3.50
2007	0.10	0.10	0.00	0.00	0.00	1.80	0.09	0.10	0.00	0.00	0.02	0.00	0.10	1.00	3.31
2008	0.10	0.10	0.00	0.00	0.00	1.80	0.09	0.10	0.00	0.00	0.02	0.00	0.10	1.00	3.31
2009	0.10	0.10	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.02	0.00	0.10	1.00	3.12
2010	2.00	0.10	0.00	0.00	0.00	1.46	0.08	0.08	0.00	0.00	0.02	0.00	0.20	1.00	4.92
2011	0.10	0.10	0.00	0.00	0.00	1.46	0.08	0.08	0.00	0.00	0.02	0.00	0.20	1.00	3.02
2012	0.10	0.10	0.00	0.00	0.00	1.07	0.05	0.06	0.00	0.00	0.02	0.00	0.20	1.00	2.60
2013	0.10	0.10	0.00	0.00	0.00	0.90	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.42
2014	0.10	0.10	0.00	0.00	0.00	0.90	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.42
2015	2.00	0.10	0.00	0.00	0.00	0.90	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	4.32
2016	0.10	0.10	0.00	0.00	0.00	0.90	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.42
2017	0.10	0.10	0.00	0.00	0.00	0.90	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.42
2018	0.10	0.10	0.00	0.00	0.00	0.90	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.42
2019	0.10	0.10	0.00	0.00	0.00	0.90	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.42
2020	2.00	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	4.58
2021	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2022	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2023	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2024	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2025	2.00	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	4.58
2026	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2027	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2028	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2029	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2030	2.00	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	4.58
2031	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2032	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2033	0.10	0.10	0.00	0.00	0.00	0.93	0.04	0.04	0.00	0.00	0.02	0.00	0.30	1.00	2.53
2034	0.10	0.10	0.00	0.00	0.00	0.93	0.04	0.04	0.00	0.00	0.02	0.00	0.30	1.00	2.53
2035	0.10	0.10	0.00	0.00	0.00	0.93	0.04	0.04	0.00	0.00	0.02	0.00	0.30	1.00	2.53
						49.31	2.39	2.64							231.06

TABLE B-8

ELEV. 940 TOUTLE SRS WITH BASE (+) DREDGING

YEAR	TOUTLE SITES NF-1 MCY	LT-3 MCY	LT-1 MCY	SUBTOTAL MCY	COWLITZ SITES RM 10-20 MCY	RM 0-10 MCY	SUBTOTAL MCY	TOTAL MCY
1986				0.0	10.8	6.1	16.9	16.9
1987				0.0			0.0	0.0
1988				0.0			0.0	0.0
1989				0.0			0.0	0.0
1990				0.0			0.0	0.0
1991				0.0			0.0	0.0
1992				0.0			0.0	0.0
1993				0.0			0.0	0.0
1994				0.0			0.0	0.0
1995				0.0			0.0	0.0
1996				0.0			0.0	0.0
1997				0.0			0.0	0.0
1998				0.0			0.0	0.0
1999				0.0			0.0	0.0
2000				0.0	1.4	0.4	1.8	1.8
2001				0.0	1.4	0.4	1.8	1.8
2002				0.0	1.3	0.3	1.6	1.6
2003				0.0	1.0	0.3	1.3	1.3
2004				0.0	1.0	0.3	1.3	1.3
2005				0.0	0.9	0.2	1.1	1.1
2006				0.0	0.8	0.2	1.0	1.0
2007				0.0	0.8	0.2	1.0	1.0
2008				0.0	0.7	0.2	0.9	0.9
2009				0.0	0.6	0.2	0.8	0.8
2010				0.0	0.6	0.2	0.8	0.8
2011				0.0	0.5	0.2	0.7	0.7
2012				0.0	0.4	0.1	0.5	0.5
2013				0.0	0.4	0.1	0.5	0.5
2014				0.0	0.4	0.1	0.5	0.5
2015				0.0	0.4	0.1	0.5	0.5
2016				0.0	0.4	0.1	0.5	0.5
2017				0.0	0.4	0.1	0.5	0.5
2018				0.0	0.4	0.1	0.5	0.5
2019				0.0	0.4	0.1	0.5	0.5
2020				0.0	0.4	0.1	0.5	0.5
2021				0.0	0.4	0.1	0.5	0.5
2022				0.0	0.4	0.1	0.5	0.5
2023				0.0	0.4	0.1	0.5	0.5
2024				0.0	0.4	0.1	0.5	0.5
2025				0.0	0.4	0.1	0.5	0.5
2026				0.0	0.4	0.1	0.5	0.5
2027				0.0	0.4	0.1	0.5	0.5
2028				0.0	0.4	0.1	0.5	0.5
2029				0.0	0.4	0.1	0.5	0.5
2030				0.0	0.4	0.1	0.5	0.5
2031				0.0	0.4	0.1	0.5	0.5
2032				0.0	0.4	0.1	0.5	0.5
2033				0.0	0.3	0.1	0.4	0.4
2034				0.0	0.3	0.1	0.4	0.4
2035				0.0	0.3	0.1	0.4	0.4
	0.0	0.0	0.0	0.0	31.1	11.6	42.7	42.7

TABLE B-9

TOTAL PROJECT COST

125-FOOT SRS WITH COWLITZ BASE-PLUS DREDGING AND KL MINIMUM LEVEE

($000,000)

Total Project Cost

SRS		98.9
Construction	63.7	
O&M	16.1	
Monitoring	5.2	
Real Estate	12.2	
Relocation	0.4	
Mitigation	1.3	
Dredging		84.8
Construction	76.15	
Real Estate	4.32	
Mitigation	4.33	
Levee (KL Min. Levee)		2.8
Cost	0.74	
Real Estate	1.10	
O&M	0.96	
Other		44.6
Revetment	0.00	
Disposal Site Rehab.	6.80	
D/S Monitoring	37.80	
TOTAL PROJECT COST		231.1

TABLE B-10
COST FLOW ($M)
PLAN -- MSRS+ DREDGING + LEVEE(KL)
(INTERMEDIATE CONDITION)

	SRS					DREDGING			LEVEE			OTHER			
	CONST	MONITOR	RE	RELOC	MITIGAT	COST	RE	MIT	COST	RE	O&M	REVET	REHAB	MON	TOTA
1986	6.00	0.00	12.20	0.40	1.30	22.81	1.61	1.58	0.00	1.10	0.00	0.00	0.10	1.80	48.91
1987	17.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.00	0.00	0.00	17.87
1988	30.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	30.52
1989	9.70	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	9.82
1990	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1991	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1992	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1993	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.22
1994	0.10	0.10	0.00	0.00	0.00	4.40	0.27	0.28	0.00	0.00	0.02	0.00	0.10	1.00	6.26
1995	0.25	0.10	0.00	0.00	0.00	7.02	0.37	0.39	0.00	0.00	0.02	0.00	0.10	1.00	9.26
1996	3.75	0.10	0.00	0.00	0.00	6.46	0.34	0.36	0.00	0.00	0.02	0.00	0.10	1.00	12.13
1997	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
1998	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
1999	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
2000	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
2001	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
2002	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
2003	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
2004	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.32
2005	0.10	0.10	0.00	0.00	0.00	2.36	0.12	0.13	0.00	0.00	0.02	0.00	0.10	1.00	3.93
2006	0.10	0.10	0.00	0.00	0.00	1.97	0.10	0.11	0.00	0.00	0.02	0.00	0.10	1.00	3.50
2007	0.10	0.10	0.00	0.00	0.00	1.80	0.09	0.10	0.00	0.00	0.02	0.00	0.10	1.00	3.31
2008	0.10	0.10	0.00	0.00	0.00	1.80	0.09	0.10	0.00	0.00	0.02	0.00	0.10	1.00	3.31
2009	0.10	0.10	0.00	0.00	0.00	1.63	0.09	0.09	0.00	0.00	0.02	0.00	0.10	1.00	3.12
2010	2.00	0.10	0.00	0.00	0.00	1.46	0.08	0.08	0.00	0.00	0.02	0.00	0.20	1.00	4.94
2011	0.10	0.10	0.00	0.00	0.00	1.46	0.08	0.08	0.00	0.00	0.02	0.00	0.20	1.00	3.04
2012	0.10	0.10	0.00	0.00	0.00	1.63	0.06	0.07	0.00	0.00	0.02	0.00	0.20	1.00	3.19
2013	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2014	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2015	2.00	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	4.58
2016	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2017	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2018	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2019	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2020	2.00	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	4.58
2021	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2022	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2023	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2024	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	2.68
2025	2.00	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.20	1.00	4.58
2026	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2027	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2028	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2029	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2030	2.00	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	4.68
2031	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2032	0.10	0.10	0.00	0.00	0.00	1.16	0.05	0.05	0.00	0.00	0.02	0.00	0.30	1.00	2.78
2033	0.10	0.10	0.00	0.00	0.00	0.93	0.04	0.04	0.00	0.00	0.02	0.00	0.30	1.00	2.53
2034	0.10	0.10	0.00	0.00	0.00	0.93	0.04	0.04	0.00	0.00	0.02	0.00	0.30	1.00	2.53
2035	0.10	0.10	0.00	0.00	0.00	0.93	0.04	0.04	0.00	0.00	0.02	0.00	0.30	1.00	2.53
															236.05

TABLE B-11

TOTAL PROJECT COST

100' - 125' MSRS WITH COWLITZ DREDGING AND KL MIN LEVEE

($000,000)

Total Project Cost

Staged SRS		99.9
Construction	64.6	
O&M	16.1	
Monitoring	5.2	
Real Estate	12.2	
Relocation	0.4	
Mitigation	1.3	
Dredging		89.7
Construction	80.8	
Real Estate	4.4	
Mitigation	4.5	
Levee (KL Min. Raise)		2.8
Cost	0.74	
Real Estate	1.10	
O&M	0.96	
Other		43.7
Revetment	0.00	
Disposal Site Rehab.	7.90	
D/S Monitoring	35.80	
	TOTAL PROJECT COST	236.1

TABLE B-12
INTERMEDIATE DREDGING- TOUTLE RIVER INITIATED

YEAR	TOUTLE SITES NF-1 MCY	LT-3 MCY	LT-1 MCY	SUBTOTAL MCY	COWLITZ SITES RM 10-20 MCY	RM 0-10 MCY	SUBTOTAL MCY	TOTAL MCY
1986	4.5	4.5	2.3	11.3	3.0	4.1	7.1	18.4
1987	4.5	4.5	2.1	11.1			0.0	11.1
1988	4.5	4.5	2.0	11.0			0.0	11.0
1989	4.5	4.5	1.6	10.6			0.0	10.6
1990	4.5	4.5	1.4	10.4			0.0	10.4
1991	4.5	4.5	1.0	10.0			0.0	10.0
1992	4.5		1.7	6.2	1.7	0.5	2.2	8.4
1993	4.5			4.5	1.7	0.6	2.3	6.8
1994	4.5			4.5	1.4	0.4	1.8	6.3
1995	4.5			4.5	1.1	0.3	1.4	5.9
1996	4.5			4.5	0.8	0.2	1.0	5.5
1997	3.5			3.5	1.2	0.3	1.5	5.0
1998				0.0	2.8	0.6	3.4	3.4
1999				0.0	2.4	0.6	3.0	3.0
2000				0.0	2.2	0.6	2.8	2.8
2001				0.0	2.1	0.5	2.6	2.6
2002				0.0	2.0	0.5	2.5	2.5
2003				0.0	1.8	0.4	2.2	2.2
2004				0.0	1.8	0.4	2.2	2.2
2005				0.0	1.7	0.4	2.1	2.1
2006				0.0	1.6	0.4	2.0	2.0
2007				0.0	1.5	0.4	1.9	1.9
2008				0.0	1.4	0.4	1.8	1.8
2009				0.0	1.4	0.4	1.8	1.8
2010				0.0	1.2	0.3	1.5	1.5
2011				0.0	1.2	0.3	1.5	1.5
2012				0.0	1.1	0.3	1.4	1.4
2013				0.0	1.1	0.3	1.4	1.4
2014				0.0	1.1	0.3	1.4	1.4
2015				0.0	0.9	0.3	1.2	1.2
2016				0.0	0.9	0.2	1.1	1.1
2017				0.0	0.9	0.2	1.1	1.1
2018				0.0	0.9	0.2	1.1	1.1
2019				0.0	0.9	0.2	1.1	1.1
2020				0.0	0.9	0.2	1.1	1.1
2021				0.0	0.9	0.2	1.1	1.1
2022				0.0	0.9	0.2	1.1	1.1
2023				0.0	0.9	0.2	1.1	1.1
2024				0.0	0.9	0.2	1.1	1.1
2025				0.0	0.9	0.2	1.1	1.1
2026				0.0	0.9	0.2	1.1	1.1
2027				0.0	0.9	0.2	1.1	1.1
2028				0.0	0.9	0.2	1.1	1.1
2029				0.0	0.9	0.2	1.1	1.1
2030				0.0	0.9	0.2	1.1	1.1
2031				0.0	0.7	0.2	0.9	0.9
2032				0.0	0.7	0.2	0.9	0.9
2033				0.0	0.7	0.2	0.9	0.9
2034				0.0	0.7	0.2	0.9	0.9
2035				0.0	0.7	0.2	0.9	0.9
	-------	-------	-------	-------	-------	-------	-------	-------
	53.0	27.0	12.1	92.1	57.2	17.8	75.0	167.1

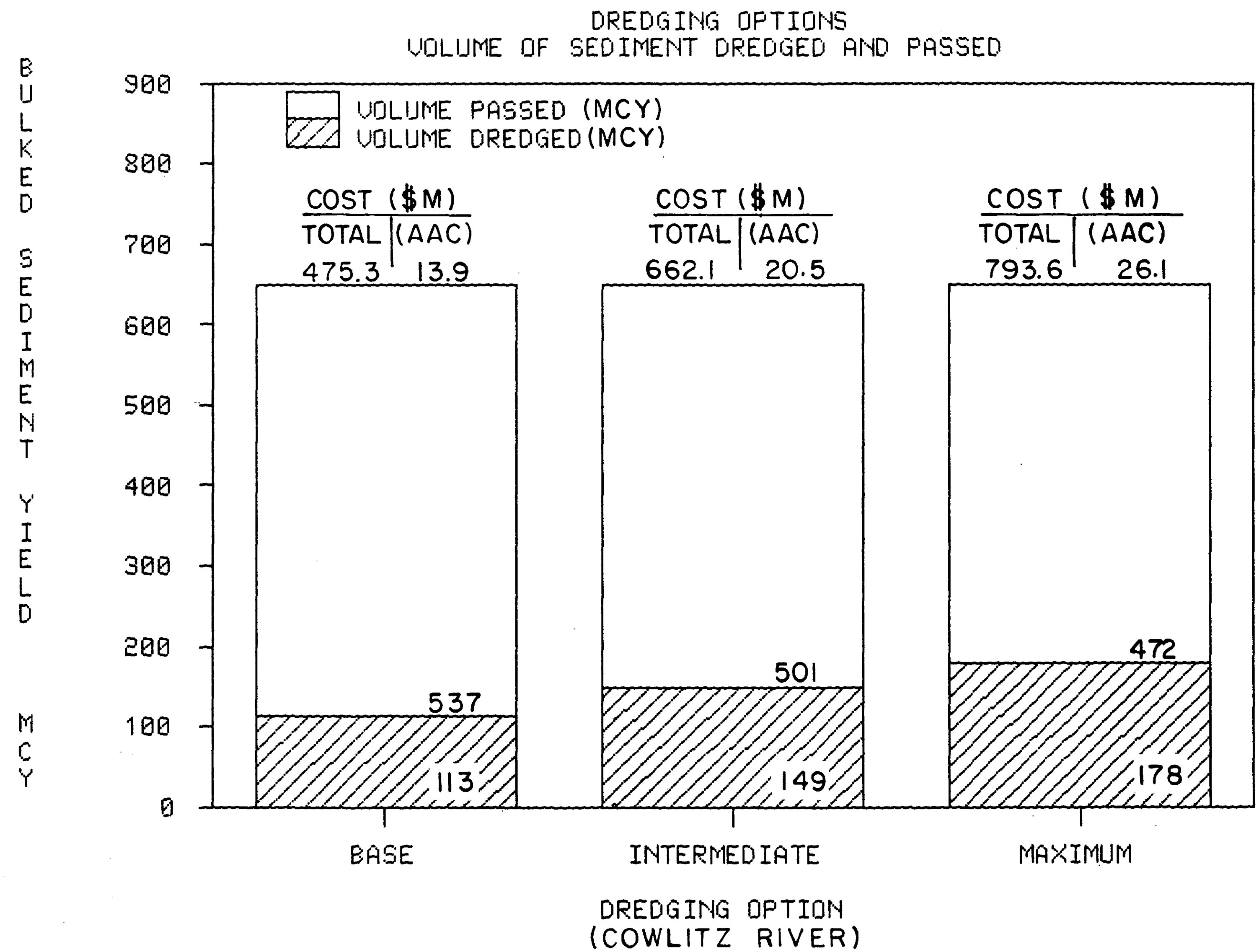
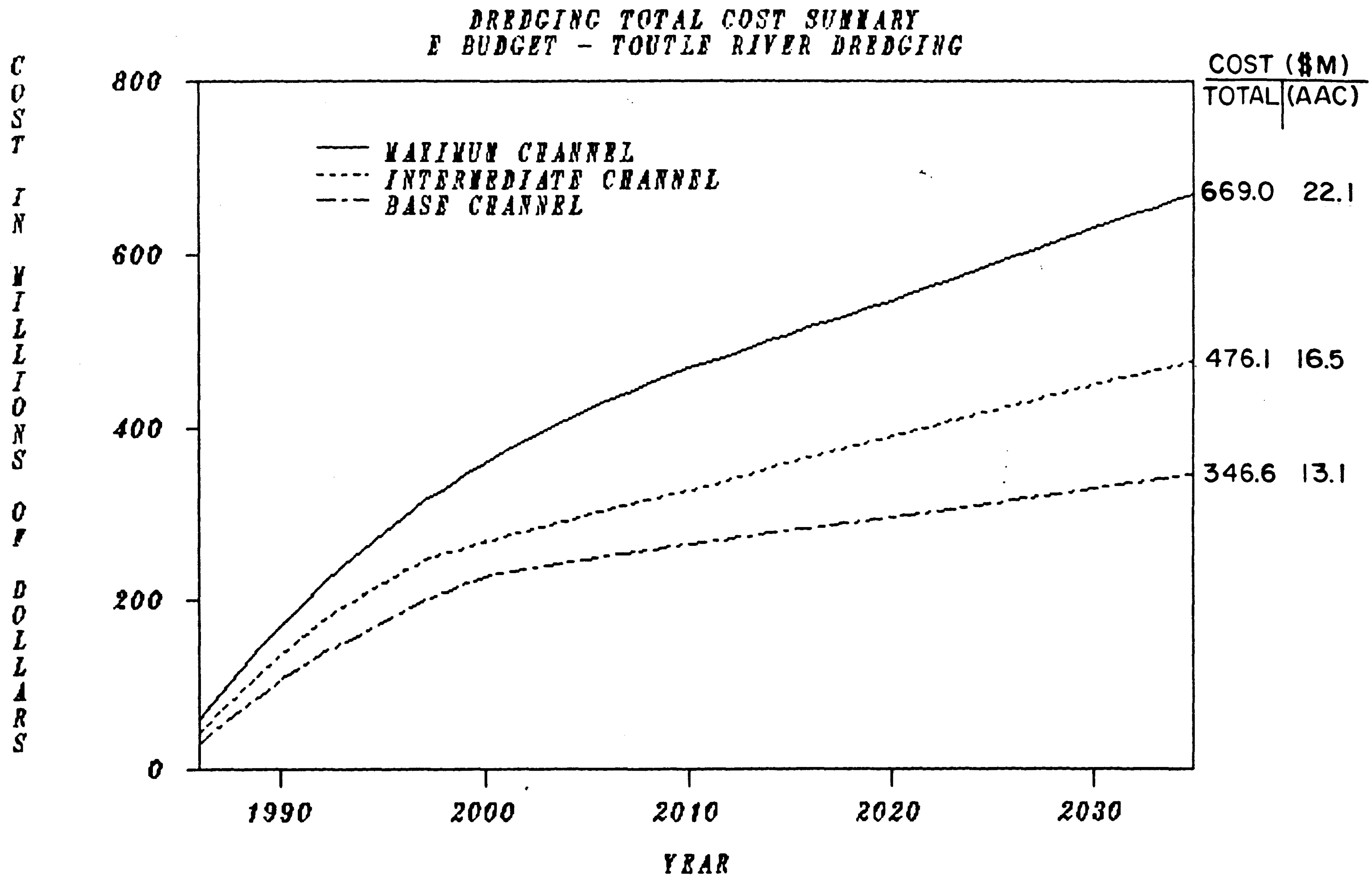

DREDGING OPTIONS
VOLUME OF SEDIMENT DREDGED AND PASSED
BULKED SEDIMENT YIELD MCY
900
800
700
600
500
400
300
200
100
0
VOLUME PASSED (MCY)
VOLUME DREDGED (MCY)
COST ($M)
TOTAL
(AAC)
475.3
13.9
COST ($M)
TOTAL
(AAC)
662.1
20.5
COST ($M)
TOTAL
(AAC)
793.6
26.1
537
113
501
149
472
178
BASE
INTERMEDIATE
MAXIMUM
DREDGING OPTION
(COWLITZ RIVER)

CHART B-1



DREDGING TOTAL COST SUMMARY
E BUDGET - TOUTLE RIVER DREDGING
COST IN MILLIONS OF DOLLARS
800
600
400
200
0
MAXIMUM CHANNEL
INTERMEDIATE CHANNEL
BASE CHANNEL
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL (AAC)
669.0 22.1
476.1 16.5
346.6 13.1

CHART B-2

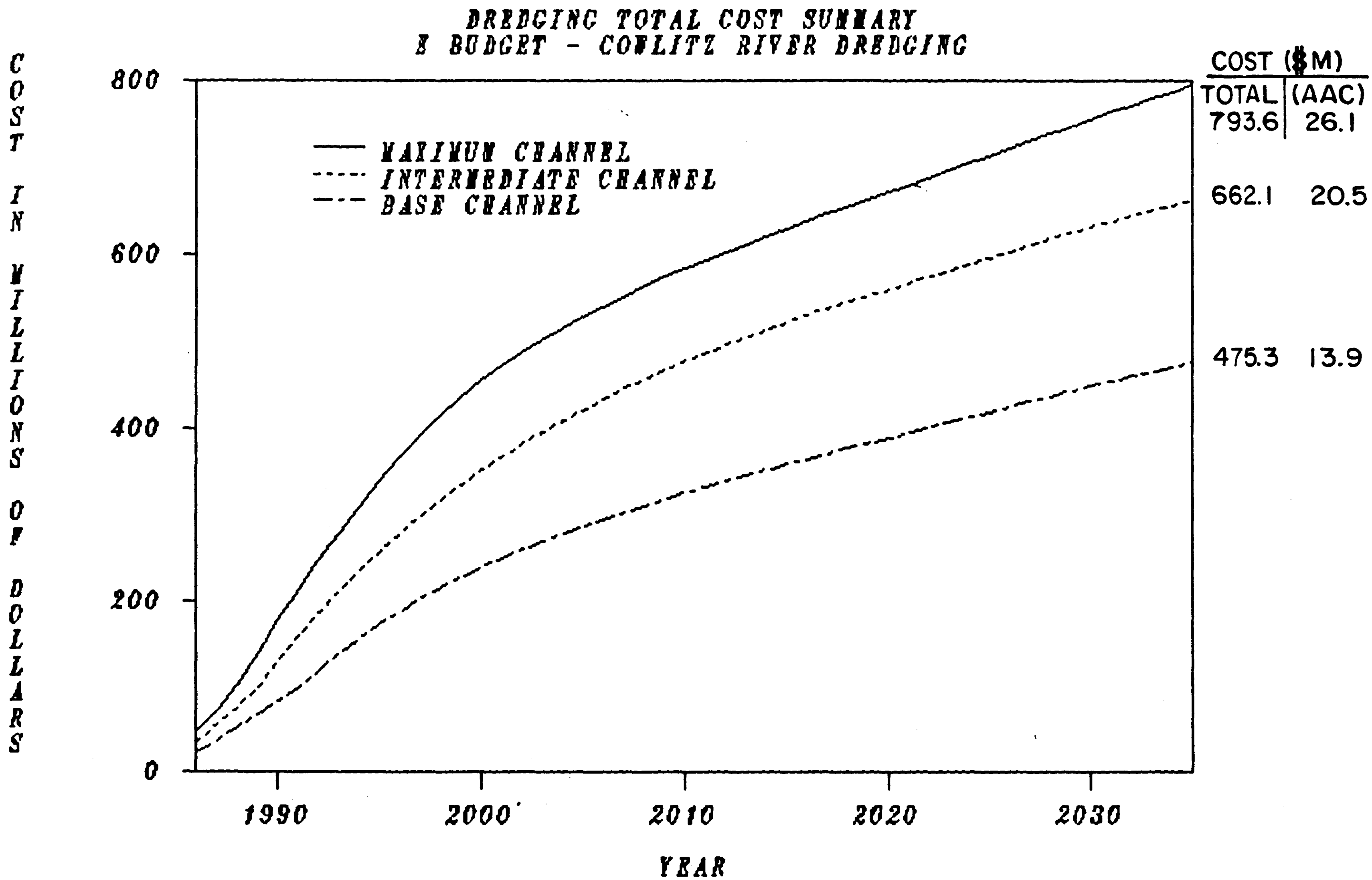

DREDGING TOTAL COST SUMMARY
E BUDGET - COWLITZ RIVER DREDGING
COST IN MILLIONS OF DOLLARS
800
600
400
200
0
MAXIMUM CHANNEL
INTERMEDIATE CHANNEL
BASE CHANNEL
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL (AAC)
793.6 26.1
662.1 20.5
475.3 13.9

CHART B-3

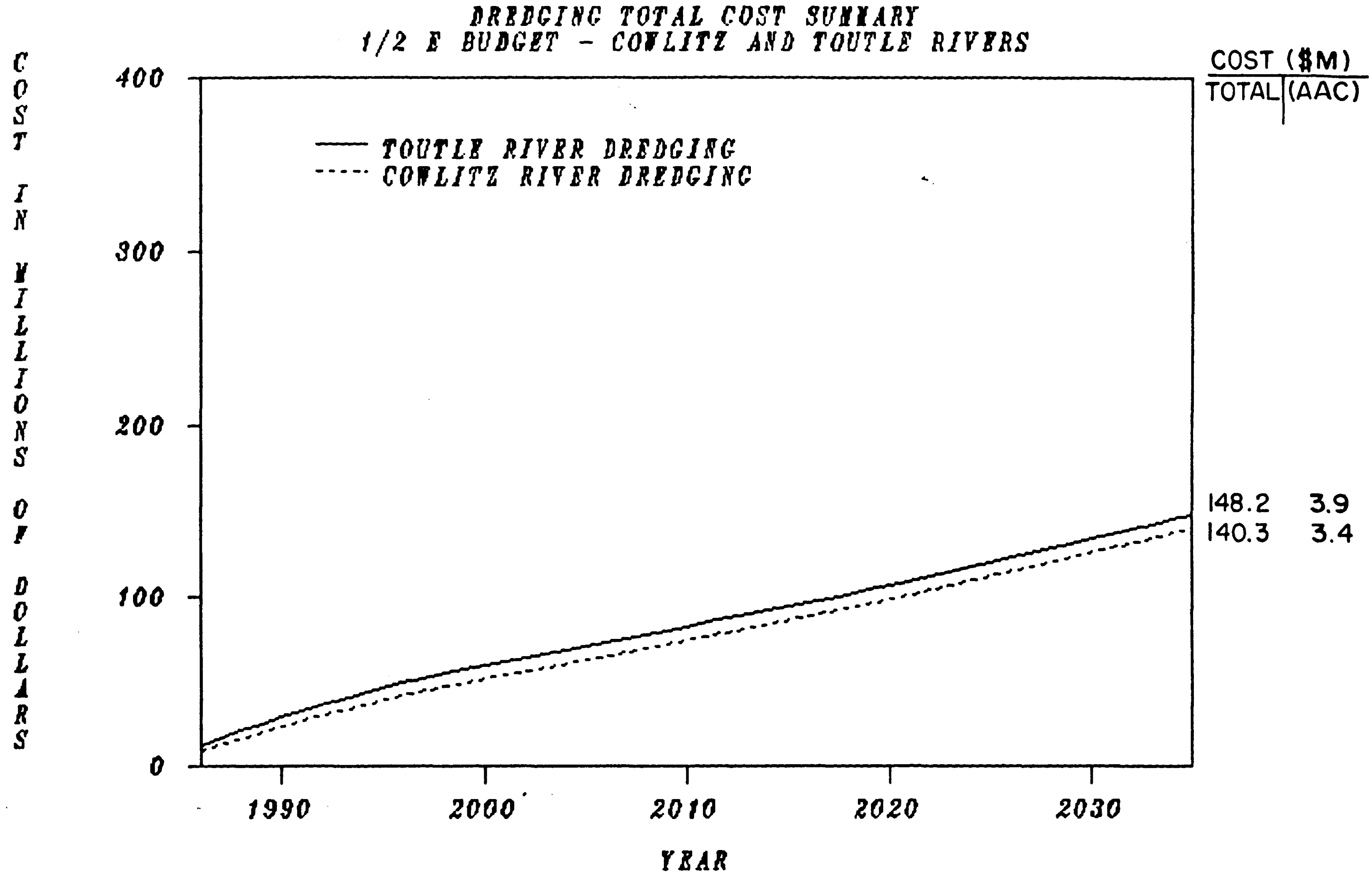

DREDGING TOTAL COST SUMMARY
1/2 E BUDGET - COWLITZ AND TOUTLE RIVERS
COST IN MILLIONS OF DOLLARS
400
300
200
100
0
TOUTLE RIVER DREDGING
COWLITZ RIVER DREDGING
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL
(AAC)
148.2 3.9
140.3 3.4

CHART B-4

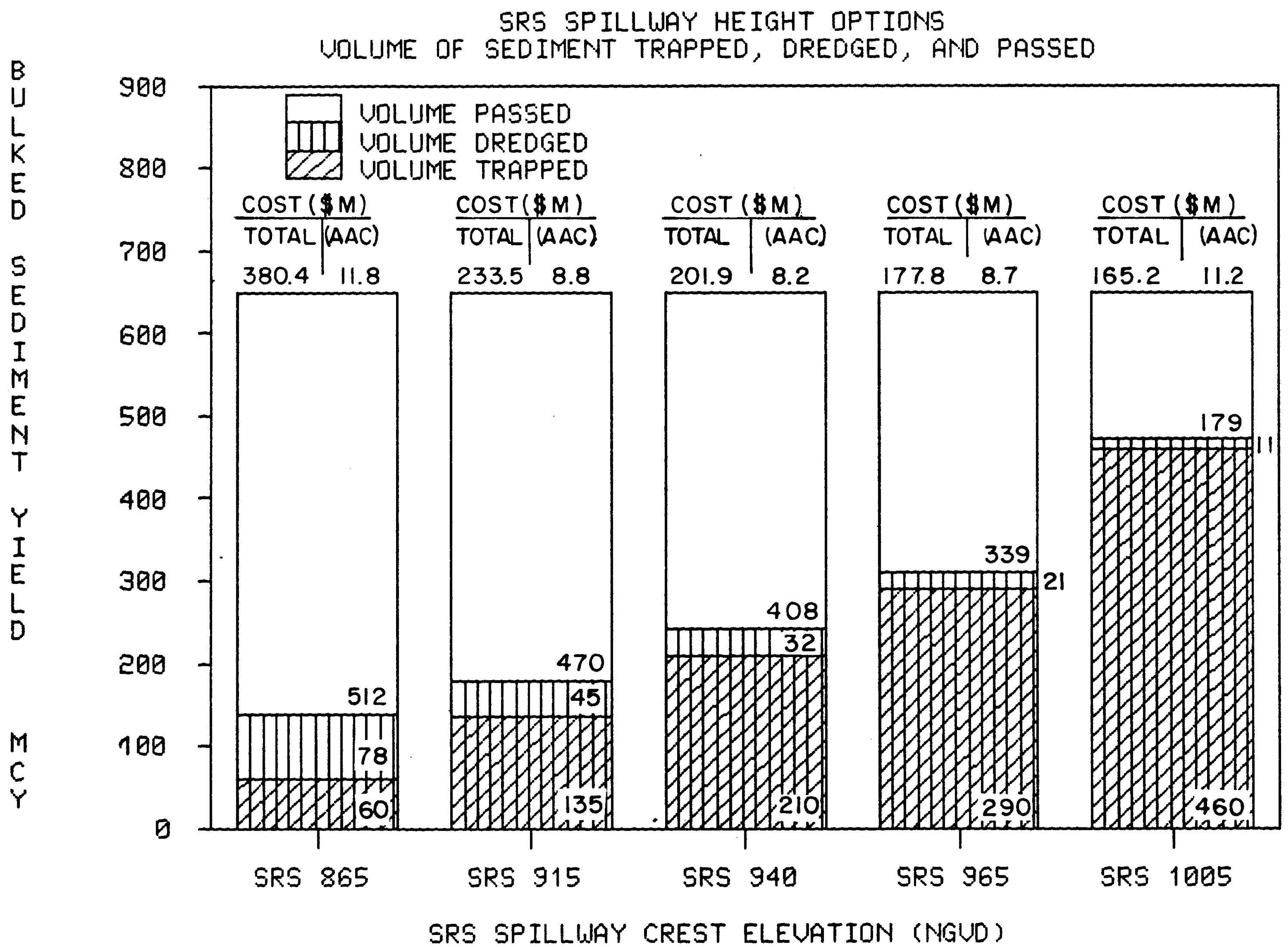

SRS SPILLWAY HEIGHT OPTIONS
VOLUME OF SEDIMENT TRAPPED, DREDGED, AND PASSED
BULKED SEDIMENT YIELD MCY
VOLUME PASSED
VOLUME DREDGED
VOLUME TRAPPED
COST ($M)
TOTAL (AAC)
380.4 11.8
233.5 8.8
201.9 8.2
177.8 8.7
165.2 11.2
512
78
60
470
45
135
408
32
210
339
21
290
179
11
460
SRS 865
SRS 915
SRS 940
SRS 965
SRS 1005
SRS SPILLWAY CREST ELEVATION (NGVD)

CHART B-5

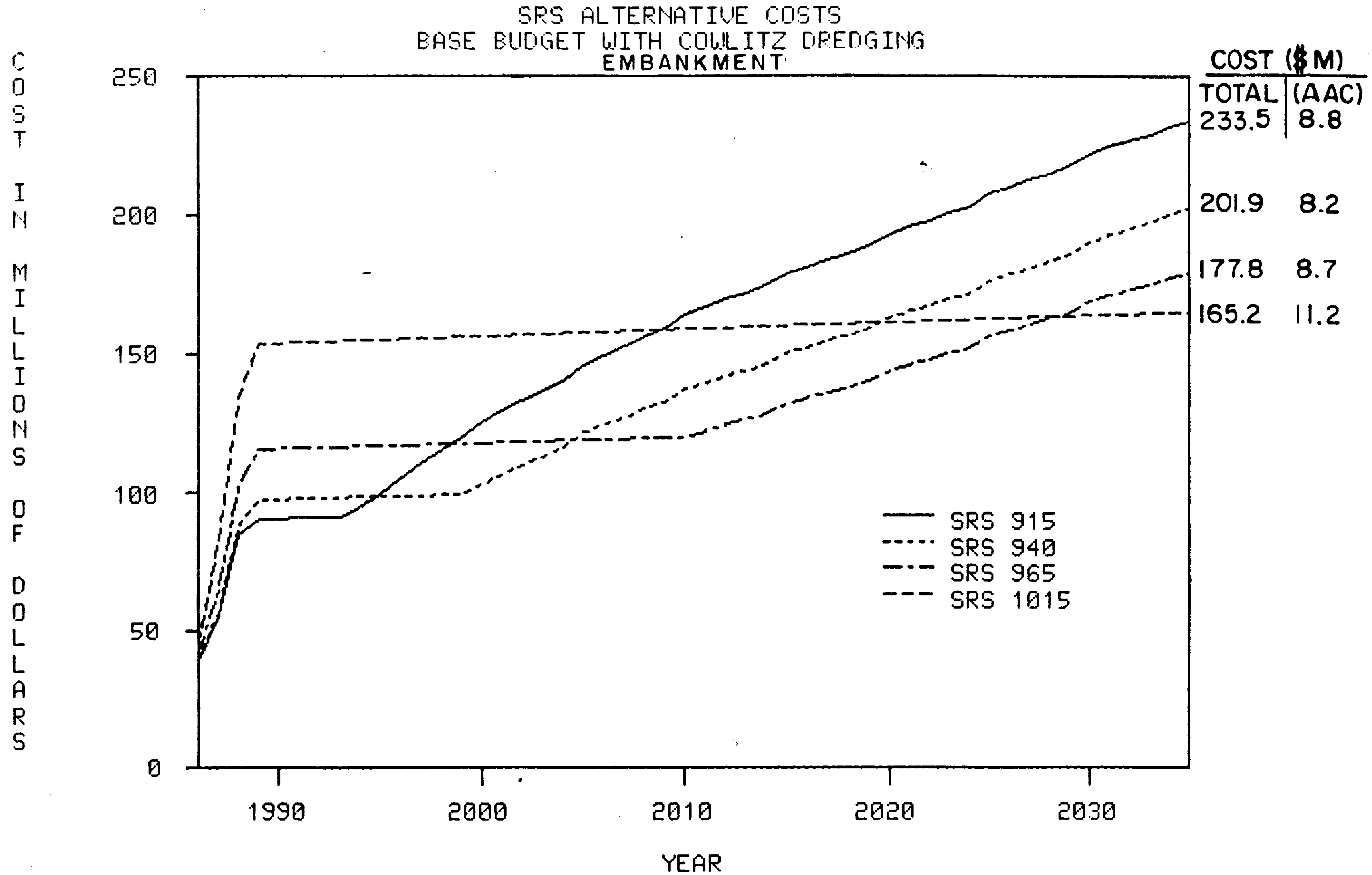

SRS ALTERNATIVE COSTS
BASE BUDGET WITH COWLITZ DREDGING
EMBANKMENT
COST IN MILLIONS OF DOLLARS
250
200
150
100
50
0
1990
2000
2010
2020
2030
YEAR
SRS 915
SRS 940
SRS 965
SRS 1015
COST ($M)
TOTAL (AAC)
233.5 8.8
201.9 8.2
177.8 8.7
165.2 11.2

CHART B-6

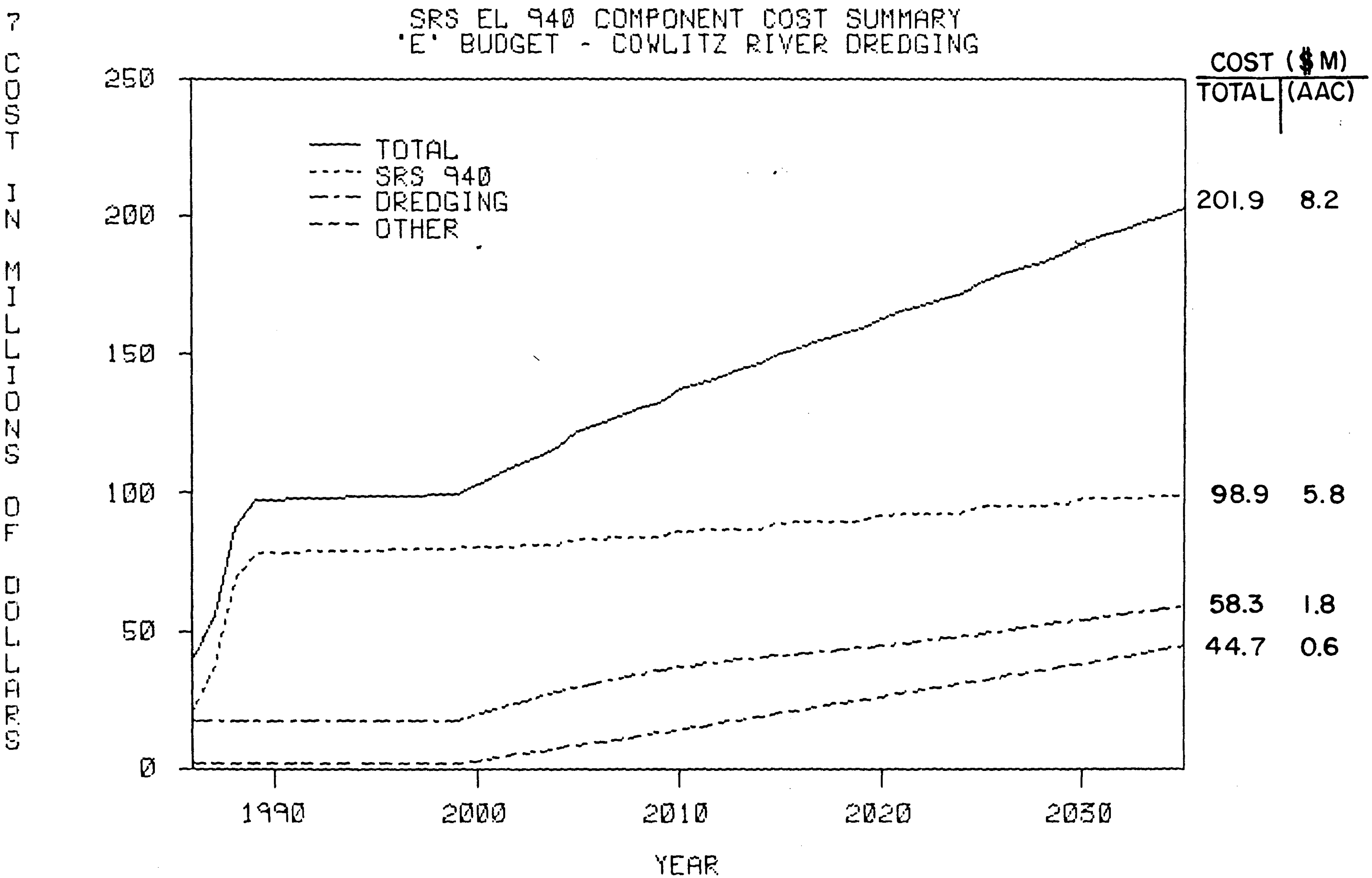

SRS EL 940 COMPONENT COST SUMMARY
'E' BUDGET - COWLITZ RIVER DREDGING
COST ($M)
TOTAL
(AAC)
TOTAL
SRS 940
DREDGING
OTHER
201.9 8.2
98.9 5.8
58.3 1.8
44.7 0.6
250
200
150
100
50
0
1990
2000
2010
2020
2030
YEAR
7 COST IN MILLIONS OF DOLLARS

CHART B-7

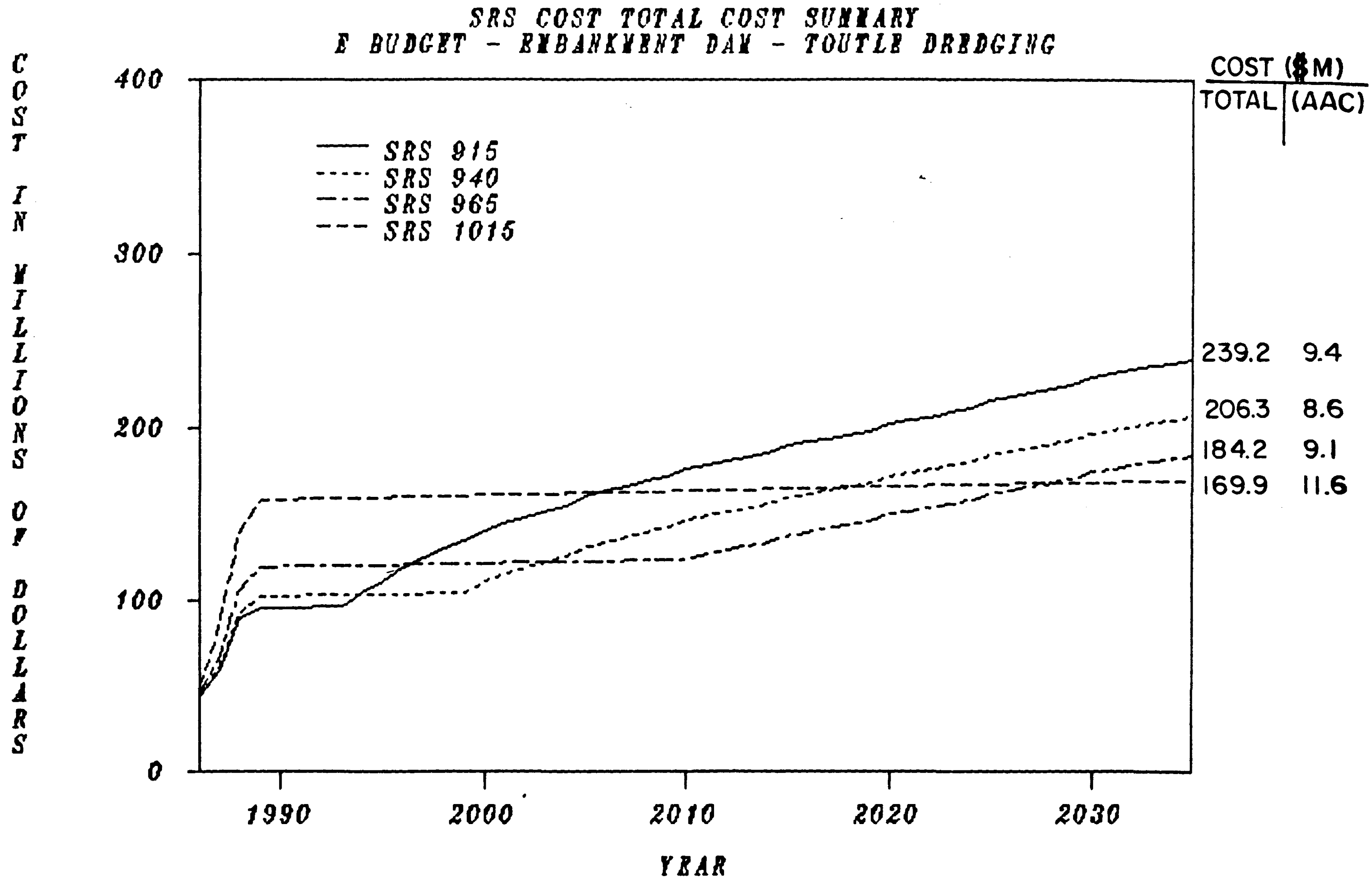

SRS COST TOTAL COST SUMMARY
E BUDGET - EMBANKMENT DAM - TOUTLE DREDGING
COST IN MILLIONS OF DOLLARS
400
300
200
100
0
SRS 915
SRS 940
SRS 965
SRS 1015
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL
(AAC)
239.2 9.4
206.3 8.6
184.2 9.1
169.9 11.6

CHART B-8

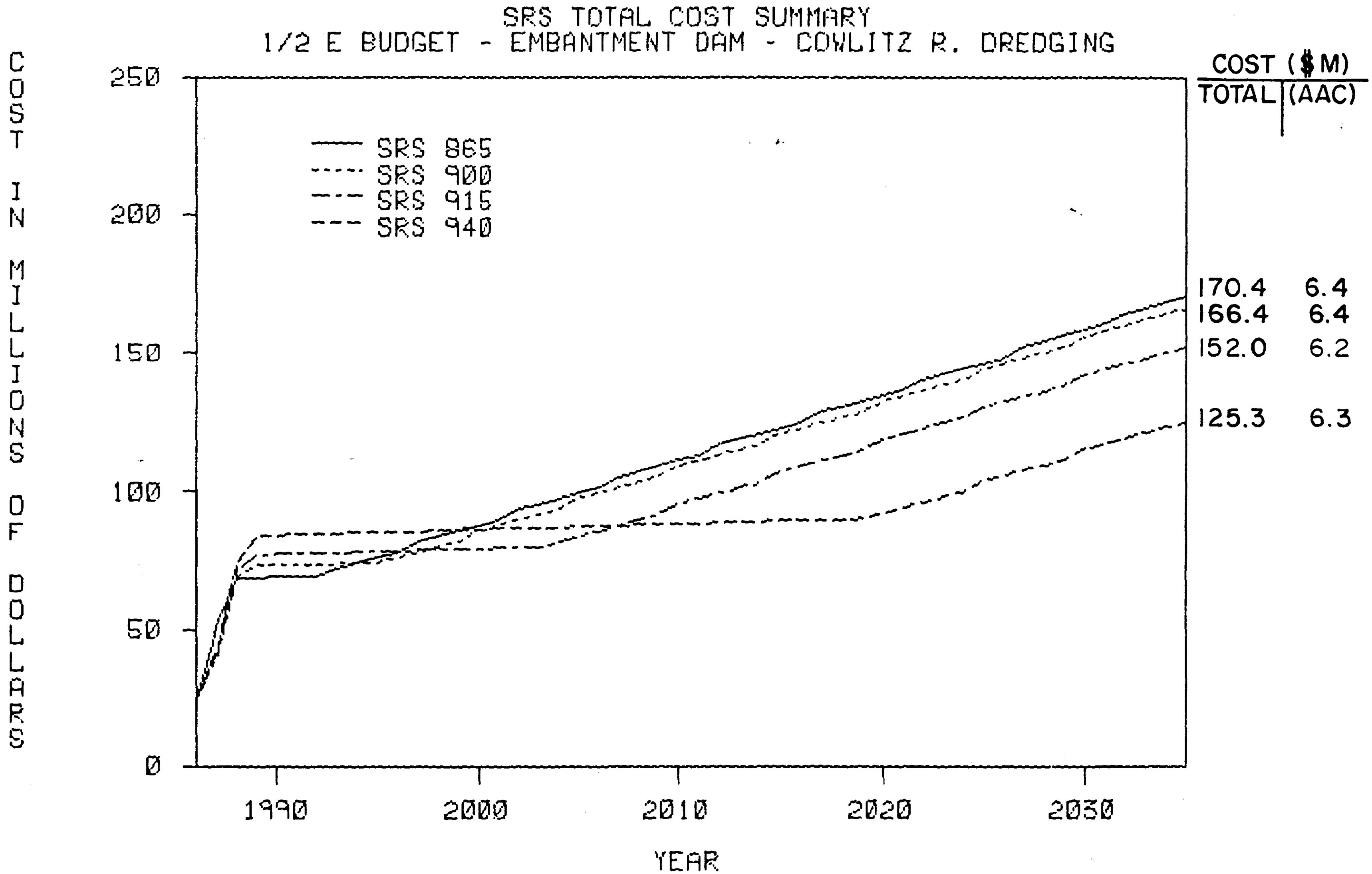

SRS TOTAL COST SUMMARY
1/2 E BUDGET - EMBANTMENT DAM - COWLITZ R. DREDGING
COST IN MILLIONS OF DOLLARS
250
200
150
100
50
0
SRS 865
SRS 900
SRS 915
SRS 940
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL (AAC)
170.4 6.4
166.4 6.4
152.0 6.2
125.3 6.3

CHART B-9

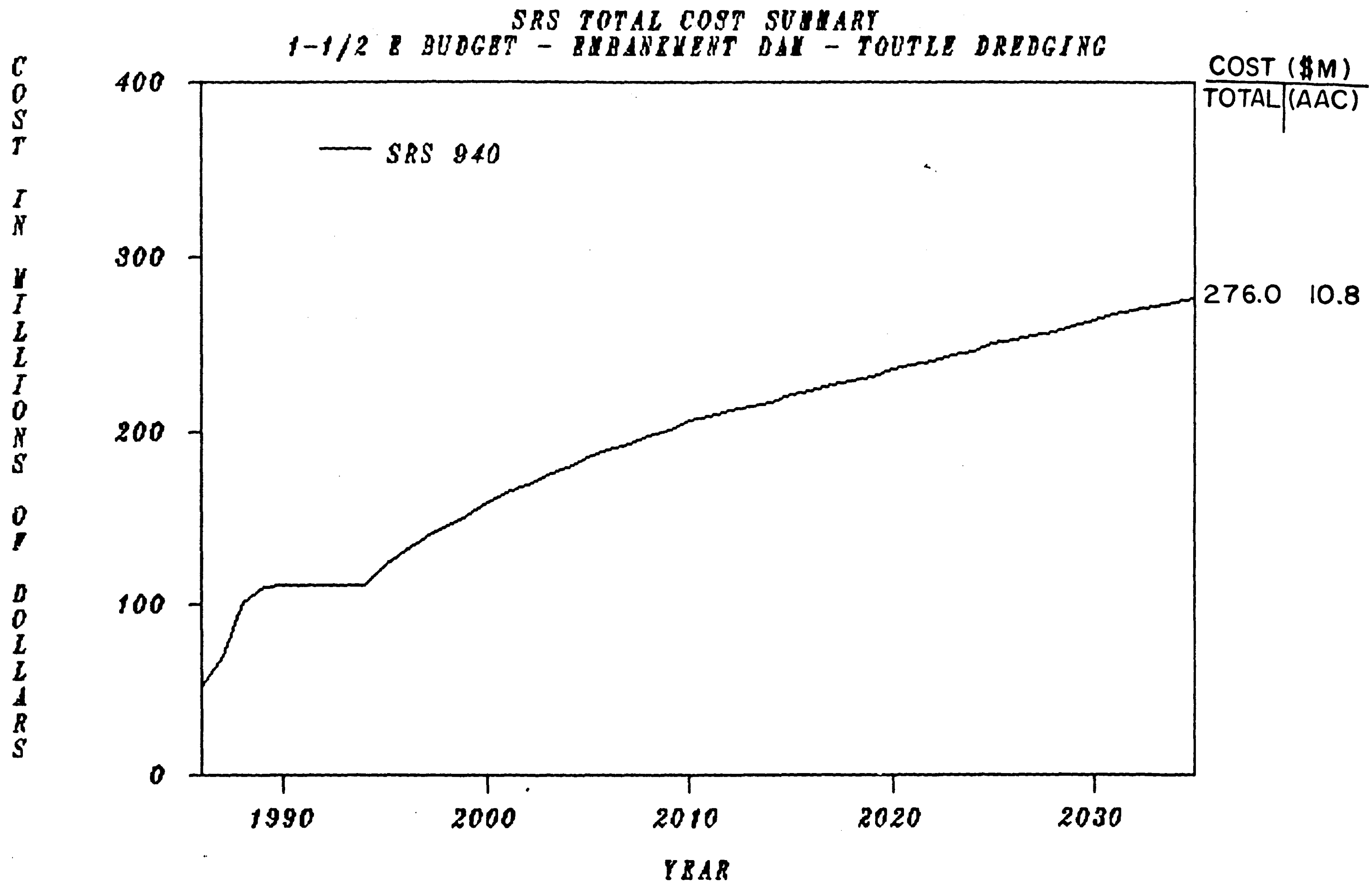

SRS TOTAL COST SUMMARY
1-1/2 % BUDGET - EMBANKMENT DAM - TOUTLE DREDGING
COST IN MILLIONS OF DOLLARS
400
300
200
100
0
SRS 940
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL
(AAC)
276.0
10.8

CHART B-10

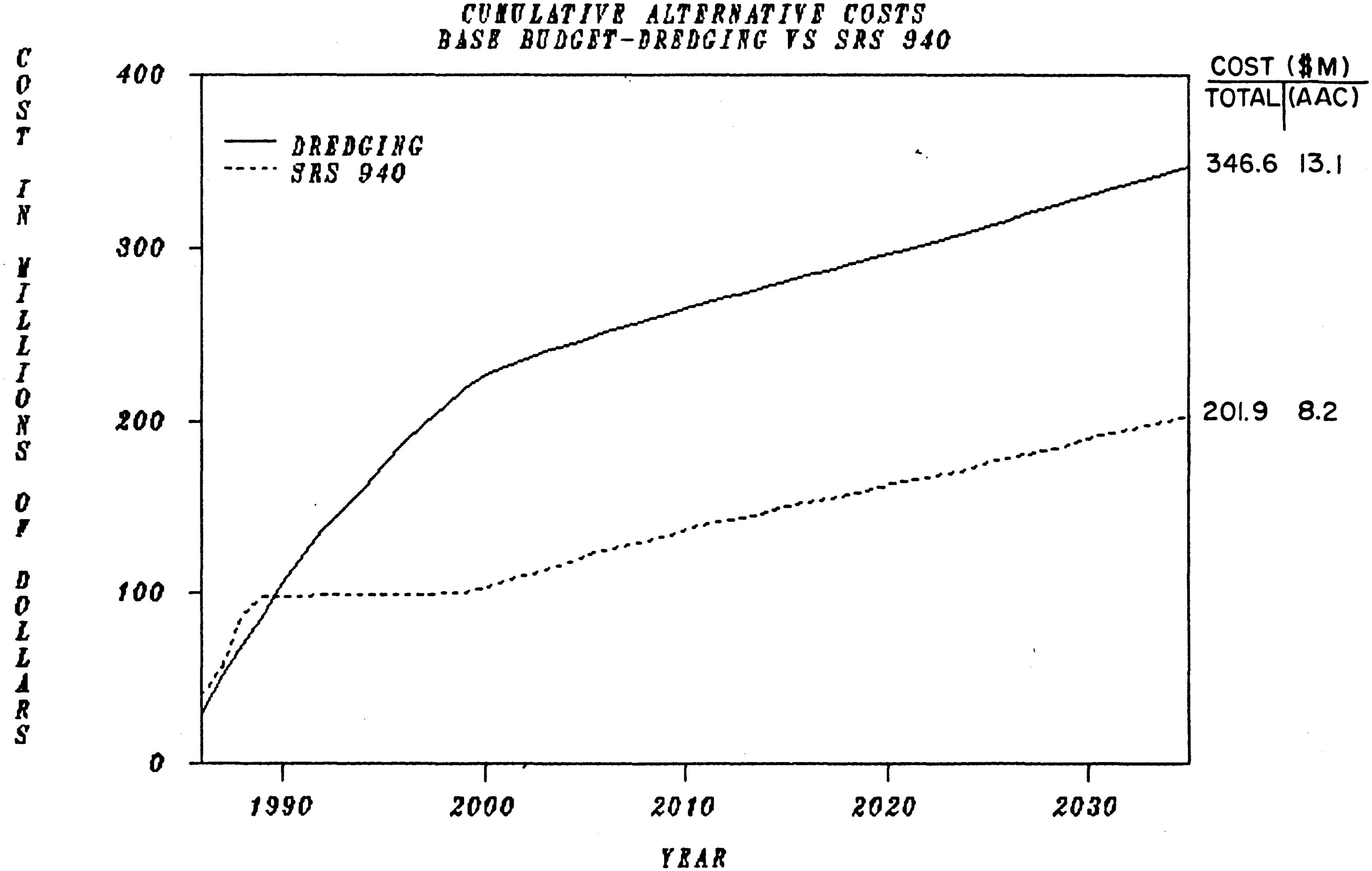

CUMULATIVE ALTERNATIVE COSTS
BASE BUDGET-DREDGING VS SRS 940
COST IN MILLIONS OF DOLLARS
400
300
200
100
0
DREDGING
SRS 940
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL
(AAC)
346.6 13.1
201.9 8.2

CHART B-11

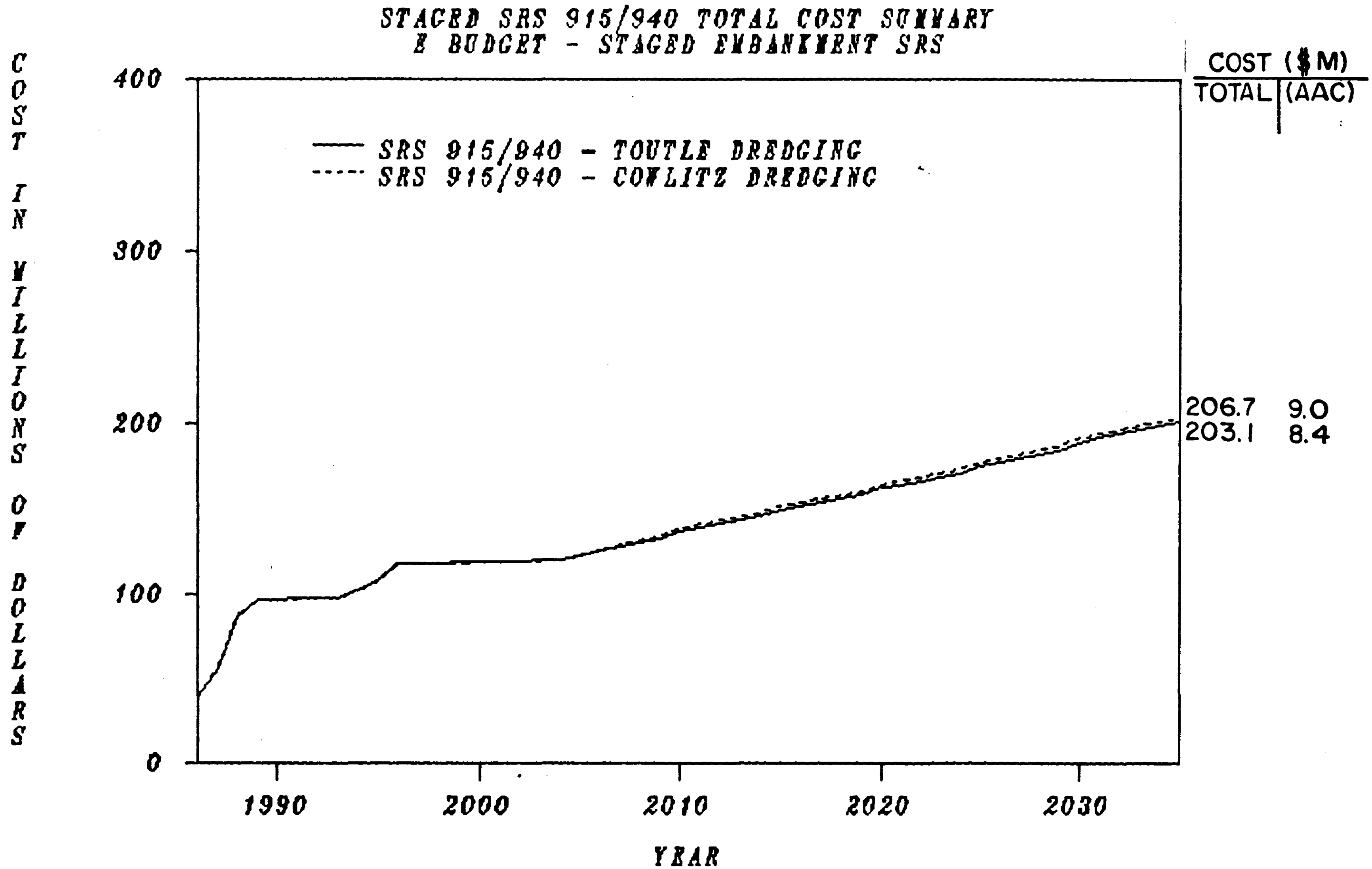
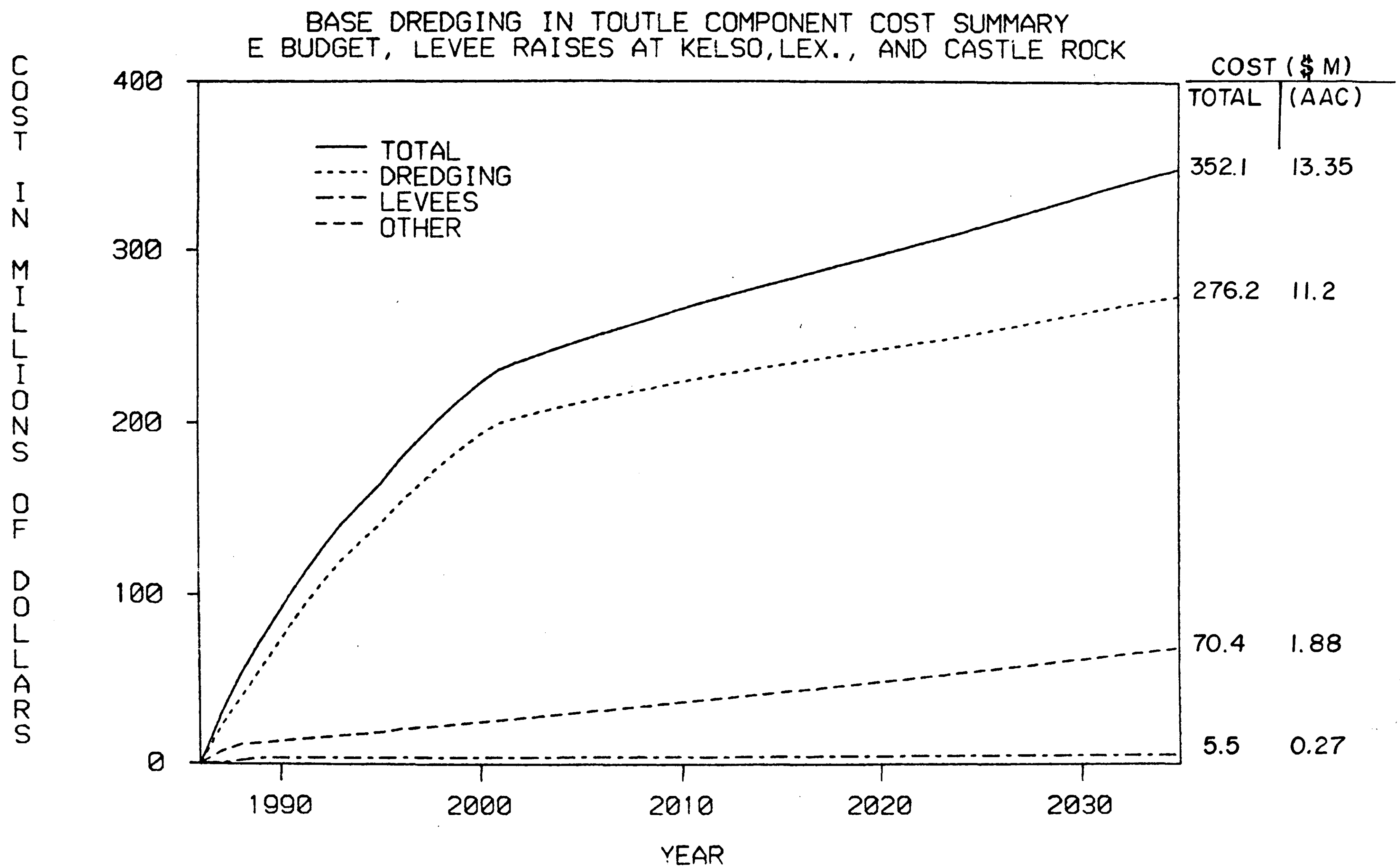
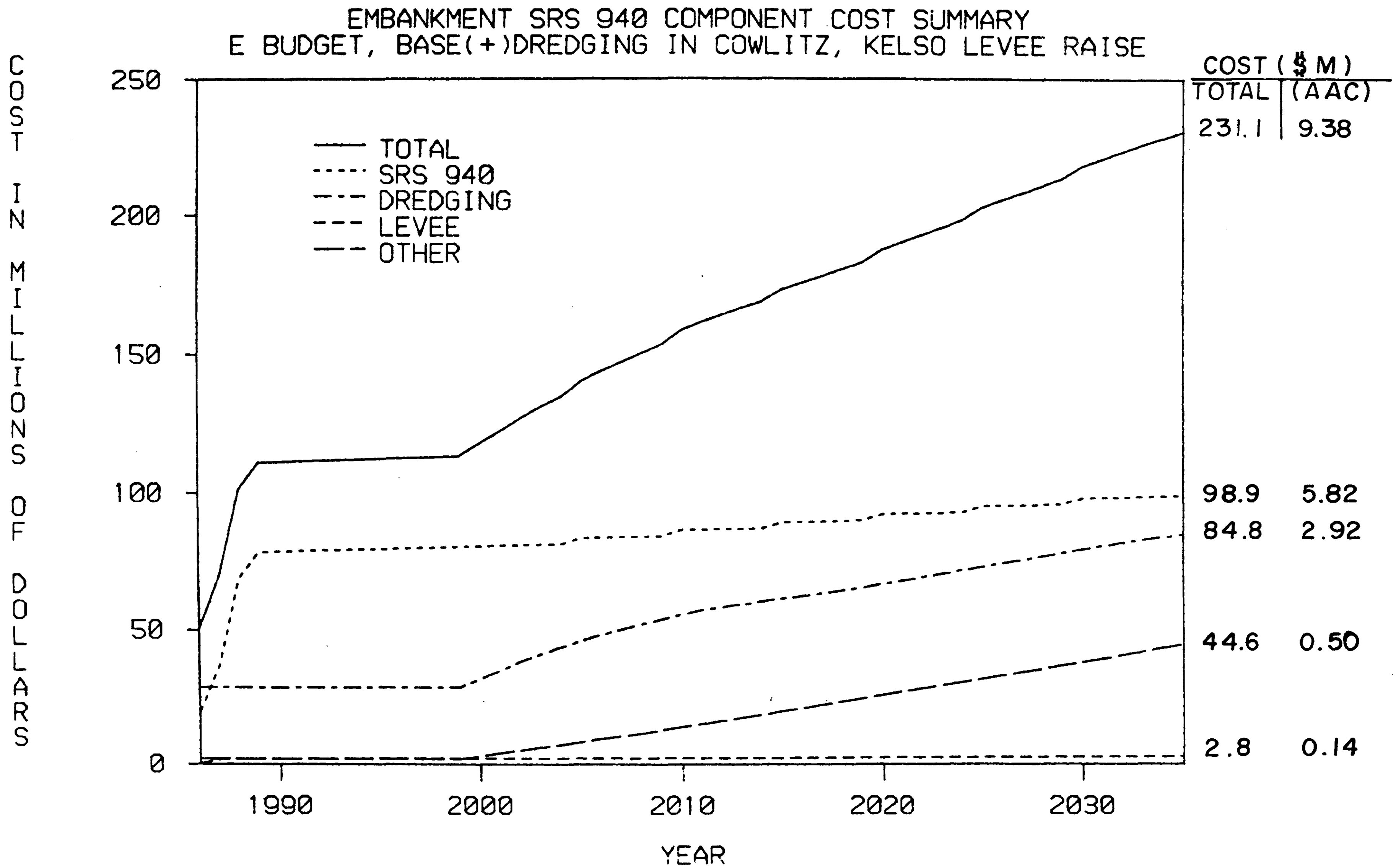

STAGED SRS 915/940 TOTAL COST SUMMARY
E BUDGET - STAGED EMBANKMENT SRS
COST IN MILLIONS OF DOLLARS
400
300
200
100
0
SRS 915/940 - TOUTLE DREDGING
SRS 915/940 - COWLITZ DREDGING
1990
2000
2010
2020
2030
YEAR
COST ($M)
TOTAL
(AAC)
206.7
9.0
203.1
8.4

CHART B-12



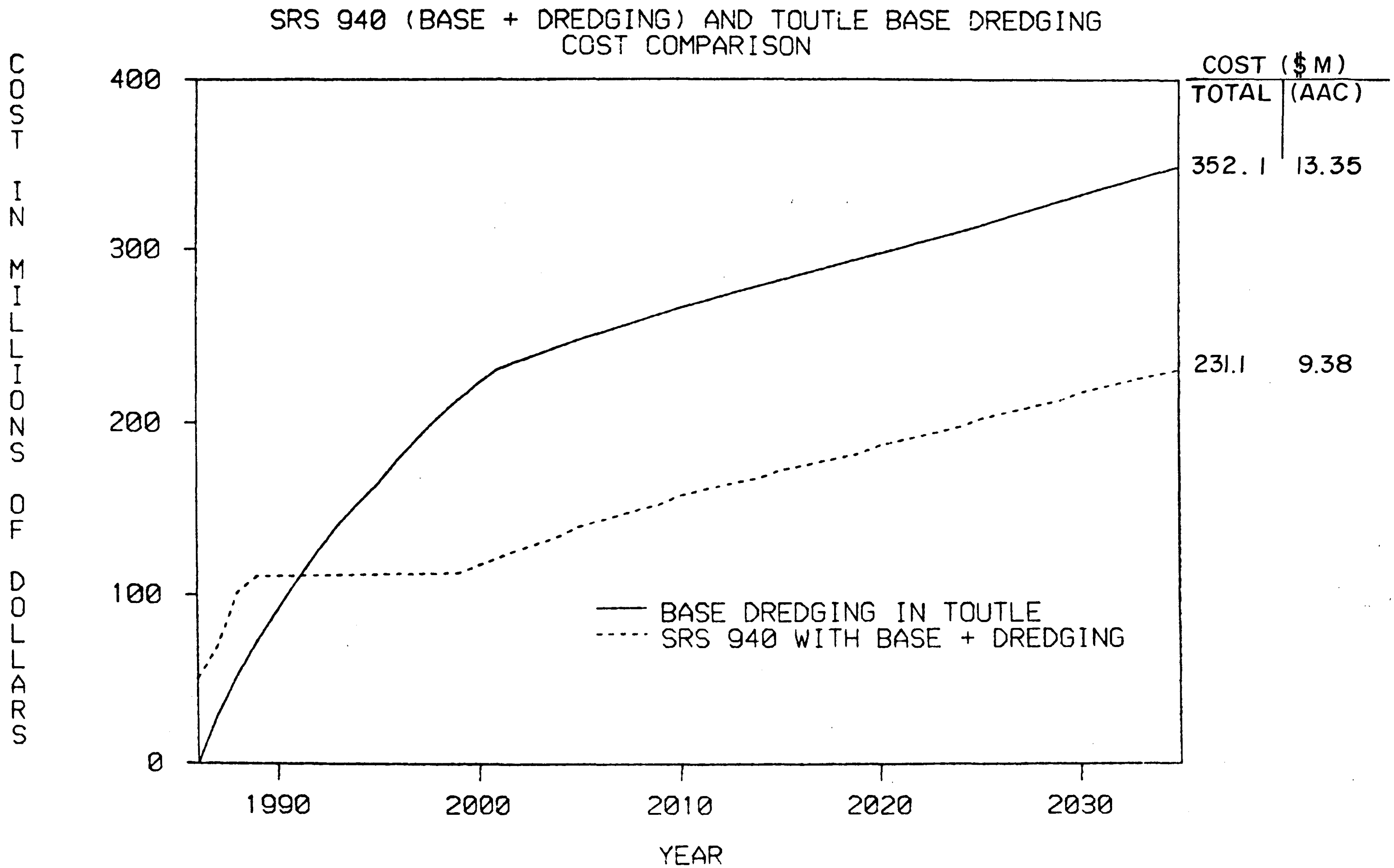
BASE DREDGING IN TOUTLE COMPONENT COST SUMMARY
E BUDGET, LEVEE RAISES AT KELSO, LEX., AND CASTLE ROCK
COST IN MILLIONS OF DOLLARS
0
100
200
300
400
TOTAL
DREDGING
LEVEES
OTHER
1990
2000
2010
2020
2030
YEAR
COST ($ M)
TOTAL
(AAC)
352.1
13.35
276.2
11.2
70.4
1.88
5.5
0.27

CHART B-13



EMBANKMENT SRS 940 COMPONENT COST SUMMARY
E BUDGET, BASE(+)DREDGING IN COWLITZ, KELSO LEVEE RAISE
COST IN MILLIONS OF DOLLARS
YEAR
TOTAL
SRS 940
DREDGING
LEVEE
OTHER
COST ($M)
TOTAL
(AAC)
231.1
9.38
98.9
5.82
84.8
2.92
44.6
0.50
2.8
0.14

CHART B-14



SRS 940 (BASE + DREDGING) AND TOUTLE BASE DREDGING
COST COMPARISON
COST IN MILLIONS OF DOLLARS
400
300
200
100
0
1990
2000
2010
2020
2030
YEAR
COST ($ M)
TOTAL
(AAC)
352.1
13.35
231.1
9.38
BASE DREDGING IN TOUTLE
SRS 940 WITH BASE + DREDGING

CHART B-15

APPENDIX C

ECONOMIC EVALUATION

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APPENDIX C

ECONOMIC ANALYSES

GENERAL

An economic base study and analysis of Cowlitz County was conducted by Seattle District, Corps of Engineers in the latter part of 1982. Full results are available in a report dated January 1983. Data contained in the report was summarized in the Comprehensive Plan, Appendix D. A brief outline of the methodology and findings, adjusted for 1985 population and employment data, is described below.

Methodology

The survey was conducted by collecting economic and demographic data for the county, region, and state. These data were then used to construct a profile of the County's economy. After the basic data were compiled, an analysis of present and future conditions was made using an input-output model of Cowlitz County developed by W. Rompa and L. Miller, A Working Model for Estimating Economic Change in Cowlitz County, Washington (September, 1980). Transactions within the local economy take place between various sectors, including manufacturing, trade, households and government. Major economic sectors of Cowlitz County were identified and firms were classified as to type of activity. The sum of all transactions between the sectors reflects the county's gross economic activity.

Economic and Socioeconomic Profile

The 1984 Washington State estimate of Cowlitz County's population was 79,900, up slightly from the official 1980 census of 79,548. County population is projected to grow at the rate of .8 percent per year from 1980 to 2005. In 1984, 51 percent of the county's population was located in Kelso (10,840) and Longview (29,820). The other three urban, incorporated areas and their 1984 populations are Woodland (2,470), Castle Rock (2,125), and Kalama (1,170).

County-wide there were 31,748 housing units in 1980. The projected growth rate for households of 1.2 percent per year from 1980 to 2005 exceeds the county population growth rate of .8 percent per year over the same period. Accordingly, household size for the county will decline from 2.70 persons per household in 1980 to 2.42 in the year 2005, reflecting the increase in one-person households and a declining birth rate.

Per capita personal income for the county exceeded that for the state since the mid-1970's, due in part to the relatively high wages paid in the forest products industry. By 1982, however, county per capita income of $10,535 was below the state's $11,446, evidencing a slowdown in foreign and domestic forest products demand.

County employment increased by an average annual rate of 1.3 percent from 1950 to 1982, although growth rates by decade within this period have fluctuated considerably because of the behavior of the manufacturing sector, which accounts for 35 percent of Cowlitz County employment and 50 percent of total wages. In this sector lumber and wood products and paper and allied products account for about 28 percent of total employment. Other major employment sectors of the county are wholesale and retail trade, services, and government. Cowlitz County's 1980 labor force participation rate for all persons age 16 and older was 59.6 percent, 76.3 percent for males and 43.6 percent for females.

Unemployment rates in Cowlitz County steadily increased from 4.4 percent in 1974 to a high of 17.5 percent in 1982. Currently Cowlitz County unemployment rates have declined to 13.2 percent (April 1985). This figure is relatively high in comparison to the state-wide rate of 8.8 percent (April 1985). The high rate reflects a loss of jobs in the forest products industries, partly because of cyclical fluctuations in the national home building industry. However, timber supply, export competition, shifts in markets, and mechanization have contributed to a structural rather than a cyclical decline in the number of persons employed in the forest products industry.

An employment forecast by the Bonneville Power Administration projects employment to grow at 1.4 percent per year from 1980 to 2005. Overall

growth during this period in the manufacturing sector will be limited by lack of growth in the forest products industries. The sectors projected to show the largest growth are services, wholesale and retail trade, and government.

Projections of Future Economic Activity

Several industries have the potential to provide jobs in Cowlitz County. Of the manufacturing industries, chemical refining and its related activities offer some job opportunities, but because they utilize capital intensive strategies to achieve increased production, the number of positions is very limited.

Another sector that has potential to provide jobs is transportation, particularly the ports. Because their growth is closely tied to national and regional economic conditions, ports have expanded services despite local economic downturns. Directly and indirectly, the ports are able to generate a considerable number of new jobs relative to other sectors. Distribution of goods may induce expansion in the transportation sector, increasing the likelihood of some new jobs.

Of the non-manufacturing activities, retail trade appears to have the most promise. This sector has a wage scale that is low relative to the forest products industry, but it can provide employment in the near term. Related to the retail trade industry is the service sector, specifically, tourism. Tourism has the potential to provide a number of service-oriented jobs.

Future Growth of Study Area

In terms of opportunities in Cowlitz County for future economic development, forest products (e.g., primary and secondary wood manufacturing) and port activities (e.g., bulk handling facilities, assembly/distribution of imports, expansion of container facilities) appear to have the greatest potential for growth. Forest lands and timber processing are and will continue to be dominant parts of the economic foundation of the county. The dependence of the

forest products industries on the ports to ship their materials and to import chemicals required in manufacturing secondary wood products underscores the importance of port activities.

Fabricated metals, chemicals, apparel, and glass products all possess the potential to provide a large number of jobs, diversify the economy and stimulate economic growth. This is also the case for the three non-manufacturing sectors of retail trade, services, and finance, insurance, and real estate.

Summary

Given the predominance of forest products and related wood products manufacturing industries in the economic structure of Cowlitz County, and considering the structural changes these industries are undergoing, it is the general conclusion of this analysis that the study area will most likely experience only modest economic development and related growth of employment and population over the next several decades.

LAND USE ANALYSIS

Summary

The area analyzed was the Cowlitz River flood plain in Cowlitz County, Washington, from the mouth of the Cowlitz to RM 21.5. A land use inventory was performed by Seattle District, Corps of Engineers under contract with the Portland District, Corps of Engineers.

The study area was divided into five subareas and delineated by the following uses:

- o Residential, Single family (includes mobile homes on lots)
- o Residential, Multiple Family
- o Residential, Mobile Home (in mobile home parks only)
- o Commercial

- o Industrial
- o Transportation/Utilities (Major roads, railroads, repair shops; aircraft and water transport; radio and televison stations; water, sewer, electrical facilities)
- o Public/Recreation (Recreation areas, churches, museums, schools, etc.)
- o Agriculture
- o Dredged Disposal
- o Vacant

Existing Land Use

Subarea 1, Longview
There is substantial high density residential and commercial development within the city limits. There are also large areas of industrial activity along the Columbia River south and east of town, with substantial vacant property. There is abundant vacant, developable land in west Longview, some in agricultural use.

Subarea 2, Kelso
Single family residential is the largest land use, with a small amount of land in commercial use. There are approximately 100 acres of manufacturing-industrial use, mainly in an industrial park south of Kelso. The majority of transportation/utilities use is in the area of the Kelso Municipal Airport. Vacant land is well distributed, with unused lots in central, west and north Kelso, and larger tracts in east and south Kelso.

Subarea 3, Lexington
Single family residential makes up a vast majority of land use. Dredged material is the next largest, followed by agricultural use and vacant land. Some commercial use is located in the small central area.

Subarea 4, Castle Rock
Single family residential is the largest usage, with dredged material next largest land use, followed by agricultural and vacant land. Some commercial use exists in the small central area.

Subarea 5, Other Cowlitz River Floodplain
One half of this area contains dredged material; agricultural use and vacant land account for another 37 percent, with a minor amount in residential use.

Future Land Use

Analysis of the most probable use of land was made for the period 1985-2000. Near-term land use plans were considered (city, county, regional), along with zoning criteria, local attitudes, and conditions influencing development. Land use changes were based on population projections, economic and social factors, comprehensive plans, building and zoning regulations, and community needs. Factors complicating the analysis were uncertainty regarding flooding related to Mount St. Helens, land needed for future dredge disposal sites, the future of the forest products industry due to preservation of forest lands in the blast area for a national monument, and the status of the overall economy.

The greatest expected changes in use are to be in Subarea 1 Longview: 457 acres now vacant to be taken up by 152 acres of single-family residential and 305 acres for industrial use. Subarea 2, Kelso is expected to have 108 acres, now vacant or in dredged material, in commercial and industrial use by 2000. The only other foreseeable development is in Subarea 3, Lexington, with 87 acres of vacant and agricultural land, and dredged material, put into single family residential use. These changes are summarized in the tables following.

POTENTIAL DAMAGES TO THE TRANSPORTATION NETWORK IN THE COWLITZ RIVER BASIN

The Study

The study outlined herein was conducted for the Portland District, Corps of Engineers by Systan, Inc., of Los Altos, California, with construction cost estimates developed by Swan Wooster Engineering, Inc., Portland, Oregon. A summary of the transportation system analysis is contained in the Comprehensive Plan, Appendix D.

The study examined the transportation network in the area affected by flooding, washouts, mudflows, and volcanic-related activity and concentrated on the

Table C-1
Cowlitz River Flood Plain
Between Toutle River and Columbia River
Existing Land Use - by Subarea
1985

	Longview*		Kelso*		Lexington		Castle Rock		Other County		Total Flood Plain	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Residential	2,705	27	555	31	185	27	142	38	215	6	3,802	23
Single Family	(2,501)		(505)		(185)		(115)		(215)		(3,521)	
Multifamily	(204)		(50)		(0)		(27)		(0)		(281)	
Commercial	469	5	125	7	5	1	20	5	40	1	659	4
Industrial	1,958	19	95	5	0	0	5	1	15	1	2,073	12
Trans/Utilities	411	4	190	10	85	12	11	3	86	3	783	5
Public/Recreation	715	7	280	15	48	7	22	6	85	2	1,150	7
Vacant	2,524	25	490	27	192	28	40	11	690	19	3,936	24
Agricultural	1,318	13	0	0	50	7	50	14	644	18	2,062	12
Dredge Spoil	0	0	90	5	125	18	80	22	1,805	50	2,100	13
TOTAL	10,100	100	1,825	100	690	100	370	100	3,580	100	16,565	100

* Includes adjacent unincorporated flood plain areas.

Table C-2
Cowlitz River Flood Plain
Between Toutle River and Columbia River
Land Use Change - by Subarea
1985 - 2000

	Longview* (Acres)	Kelso* (Acres)	Lexington (Acres)	Castle Rock (Acres)	Other County (Acres)	Total Flood Plain (Acres)
Residential	+152	0	+87	0	0	+239
Single Family	(+152)	0	(+87)	(0)	(0)	(+239)
Multifamily	(0)	(0)	(0)	(0)	(0)	(0)
Commercial	0	+58	0	0	0	+58
Trans/Utilities	0	0	0	0	0	0
Industrial	+305	+50	0	0	0	+355
Public/Recreation	0	0	0	0	0	0
Vacant	-457	-50	-54	0	0	-561
Agriculture	0	0	-2	0	0	-2
Dredge Spoil	0	-58	-31	0	0	-89
TOTAL	0	0	0	0	0	0

* Includes adjacent unincorporated flood plain areas.

Table C-3
Cowlitz River Flood Plain
Between Toutle River and Columbia River
Future Land Use - by Subarea
2000

	Longview*		Kelso*		Lexington		Castle Rock		Other County		Total Flood Plain	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Residential	2,857	28	555	31	272	39	142	38	215	6	4,041	24
Single Family	(2,653)		(505)		(272)		(115)		(215)		(3,760)	
Multifamily	(204)		(50)		(0)		(27)		(0)		(281)	
Commercial	469	5	183	10	5	1	20	5	40	1	717	4
Trans/Utilities	411	4	190	10	85	12	11	3	86	3	783	5
Industrial	2,263	22	145	8	0	0	5	1	15	1	2,428	15
Public/Recreation	715	7	280	15	48	7	22	6	85	2	1,150	7
Vacant	2,067	21	440	24	138	20	40	11	690	19	3,375	20
Agricultural	1,318	13	0	0	48	7	50	14	644	18	2,060	13
Dredge Spoil	0	0	32	2	94	14	80	22	1,805	50	2,011	12
TOTAL	10,100	100	1,825	100	690	100	370	100	3,580	100	16,565	100

* Includes adjacent unincorporated flood plain areas.

major north-south corridor which contains Interstate Highway 5 (I-5) and the Burlington-Northern Railroad line. Waterborne transportation was not included.

Economic impacts analyzed were the costs of reconstruction and damage repair, and costs of rerouting traffic during blockage and reconstruction. To examine the latter a number of scenarios were posited - various conditions that might reasonably occur - and the rerouting costs of each determined. The costs of repairing or reconstructing bridges and roads vary a great deal hence were arrived at separately.

The Transportation Network

The network's dominant features are Highway I-5 and the Burlington-Northern Railroad tracks. Highway I-5 is the major route for vehicular traffic between Portland, Oregon, and Seattle, Washington, as well as for considerable local traffic. The Burlington-Northern facilities serve that major railroad and Union Pacific Railway and AMTRAK passenger trains as well. Secondary roads (e.g., Route 411) and railroads (the Columbia Cowlitz) are of importance, but from a regional as well as local perspective, I-5 and the Burlington-Northern tracks have the greatest potential for economic disruption and cost. Both I-5 and the Burlington-Northern tracks are particularly vulnerable where their bridges cross the Toutle River near its confluence with the Cowlitz.

Specific Costs

Rerouting Vehicular Traffic

Seven highway rerouting scenarios were postulated by examining the detour routes that would be used when the transportation system is disrupted. The additional rerouting costs were identified for each detour scenario using the following approach:

1. Alternative detour routes were identified by examining existing regional contingency plans of the state and county, and the least costly detour in each case was used to estimate travel costs. It was generally

assumed that no economic activity would be interrupted, displaced, or transferred solely as a result of damage to the transportation network.

2. For each scenario the handling capacity of each stretch of road was determined by using standard highway design criteria and considering normal traffic levels on the alternate routes. When rerouted traffic exceeded capacity, the traffic was again rerouted to the next most feasible alternative route.

3. The additional miles and time needed to complete the detour were identified. This was done by adjusting travel speeds to reflect road gradient, horizontal curvature, and the queuing delay effects associated with stop-and-go traffic.

4. The vehicular operating costs were identified by vehicular type using the AASHTO manual[1] and were adjusted to reflect current price levels.

5. The additional travel time costs were computed by using the automobile driver and the adult passenger and truck driver values recommended in the AASHTO manual.[1] At current price levels, these two values were $10 per vehicle hour for passenger cars and $14 per vehicle hour for trucks.

The associated rerouting costs for each scenario are tabulated below:

Highway Reroute Scenarios	Thousands of $ Per Day
I-5 bridges and all adjacent routes blocked: use of Routes 101 and 97 to detour around the Basin	2,700.7
Multiple blockage of I-5 and adjacent routes: use of Routes 101 and 97 to detour around the Basin	3,052.0
I-5 bridges blocked; use of Route 4/506	1,351.5
I-5 bridges blocked: use of old Highway 99	230.6
I-5 bridges blocked; use of 411/506 and old Highway 99	75.0
I-5 bridges blocked; short four-lane detour on old Highway 99	3.2
I-5 open; Route 411 blocked south of Castle Rock	0.7

1. A Manual on User Benefit Analysis on Highway and Bus Transit Improvements, American Association of Highway and Transportation Officials, Washington D.C., 1977.

Rerouting Rail Traffic

A prolonged break in, or blockage of, the Burlington-Northern tracks would require rerouting east along the Columbia River, north to Yakima, Washington, then west over Stampede Pass to Auburn and the Seattle area. The rerouting, taking Vancouver, Washington, as the starting place, would be 453 miles, as compared to the normal 155 miles between Vancouver to Auburn by the Cowlitz River route. AMTRAK would likely reroute its passengers by bus, unless I-5 were closed also. The freight rerouting costs were computed by examining standard Interstate Commerce Commission rates and estimating additional operating costs for the types of traffic to be rerouted. The costs varied between \$.35 and \$.42 per car mile. The additional cost of bus transportation, including passenger time, was used to compute detour costs for AMTRAK. Rerouting costs from closure of the Burlington-Northern tracks are summarized below.

	Additional Costs per Day	
Railroad Company	I-5 Open	I-5 Closed
Burlington Northern	\$62,600	\$62,600
Union Pacific	4,300	4,300
AMTRAK passenger service	2,300	(32,500)
Total reroute costs	\$64,600	\$99,400

Repair, Reconstruction, and Replacement of Structures

If bridges across the Toutle and Cowlitz Rivers were destroyed or severely damaged, temporary structures would be required while major facilities are rebuilt. Costs and construction periods of temporary structures were developed from engineering data.

Costs of replacing the principal bridges of the network were also developed, along with construction periods. Other costs, such as removal of mud from roadways, were estimated and considered in the various sets of conditions studied.

Total Costs

If the three bridges across the Toutle River (I-5, Burlington-Northern Railroad, and old Highway 99) were destroyed, total losses could range from $98 million to $536 million. Four hypothetical cases were developed to exemplify how rerouting and replacement costs could be applied to estimate economic losses for a particular set of conditions. No prediction was made as to which case is more likely to occur.

Average Annual Transportation Damages

The transportation loss scenarios, utilizing cost data in the report, were incorporated into the flood damage analysis by determining at what flood stages the different scenarios would occur. The stage-damage relationship is shown on figure C-8. The stage-damage curve was combined with stage frequency data over time to derive average annual damages. Average annual transportation losses under the base condition are $132,000.

STAGE-DAMAGE ANALYSIS

General

Stage-damage analysis is a method of measuring potential damages to a flood plain area. This type of analysis measures flood-related damages for a series of hydrologic events which can be expected to occur in a given river basin or geographic area. It allows integration of damage costs with the probability, or frequency of occurrence of flood events. The result is an estimate of average annual flood damages which can be expected to occur in any given year. A comparison can then be made between damage/frequency under existing or no-action conditions and damage/frequency of proposed actions, to measure reduction in damages, or benefits, attributable to those actions. This method of analysis is used in this document to provide a measure of damages which would be incurred over a range of probable flood events on the Cowlitz and Toutle Rivers.

In this section the economic impact of various proposed solutions to the current flood threat in the Cowlitz and Toutle Rivers is analyzed. The base condition is compared to the no-action condition to demonstrate that continued maintenance of the base condition is justified. Damage reduction estimates are presented for various alternative measures, including dredging, levee improvement, single and multi-stage single retention structures (SRS's and MSRS's), and the most feasible combinations of these alternative measures. A National Economic Development (NED) solution to the flooding problem on the Cowlitz and Toutle Rivers is identified from among these alternatives, based on a comparison of average annual benefits and costs for protection provided by each alternative compared to the base condition.

The NED plan and the most cost effective dredging alternatives are then subjected to further analysis using sediment budgets 1/2 and 1-1/2 times the baseline sediment budget to determine how sensitive the NED plan is to greater or lesser volumes of sediment infill. Additionally, the sensitivity of sizing these alternatives for larger or smaller sediment loads is analyzed.

A risk analysis is included to test the effect of an additional low frequency flood, on the NED plan and the most cost effective dredging option.

Methodology

The stage-damage method requires the development of a flood plain inventory which includes identification of all improvements, or damage-susceptible property, in a given area or river reach (see LAND USE in this appendix). Each improvement is delineated by type, location, and ground floor elevation. The value of each improvement and its contents is determined from tax assessment records, valuation formulae, or individual appraisal.

Flood damage estimates were derived from two sources: Federal Insurance Administration tables, and damage assessment formulae previously developed by engineering consultants for the Corp's Willamette River Basin Flood Damage Study. This latter methodology estimates flood damages to residential, commercial, and industrial structures and contents, clean-up, utilities, etc. Application of these data results in estimates of damages to each type of improvement at given levels of inundation. In the case of specialized properties, structures, and contents were appraised individually by a real estate appraisal specialist.

Damages to improvements are then calculated for a series of water surface elevations. Damages at various flood levels are computed using depth-damage data developed by the Federal Insurance Administration, and using depth-damage relationships developed for Portland District by an engineering consulting firm. Damages have been updated to a fiscal year 1985 price level.

Primary Data, Inventory

Using the foregoing flood plain inventory methodology, an inventory of the City of Longview was performed by contract. Similar data for Kelso, Lexington, Castle Rock and unleveed areas, were compiled by Portland District. All

improvements were inventoried to determine type of improvement (e.g., residence, mobile home, commercial property, utilities), location, ground floor elevation, and value. Estimates of potential damages to major highways and railroads, bridges, and related transportation facilities were developed by a consultant under contract to Portland District.

Flood Damage at Longview

Flood damages were computed for improvements in Longview for various water surface elevations. Flooding was judged to begin with breaching of the existing levee along the Cowlitz River at its lowest elevations, with subsequent ponding occurring at the lowest ground elevation within that diking district. Damages were computed for 5-foot vertical intervals within Longview to reflect this ponding effect which would occur if the levee was breached.

Flood Damage at Kelso and Upstream

Stage-damage relationships were also developed for Kelso and all leveed and unleveed areas upstream of Longview-Kelso to the confluence of the Cowlitz and Toutle Rivers.

Stage-Damage Curves

Following computation of damages at different flood levels, stage-damage curves were constructed for 8 sub-reaches of the 4 major reaches along the lower 25 miles of the Cowlitz River (see Figures C-1 through C-8). These curves reflect the potential flood damages to improvements within each sub-reach related to water surface elevations. Results from the economic base and land use studies indicate that growth within the flood plain is relatively static and no significant future development is anticipated that would impact potential future damages. Therefore, it is assumed that stage-damage relationships will remain relatively constant over the project life.

Integration with Hydrologic Frequency Data

Data from the stage-damage curves were integrated with stage-frequency relationships for the Cowlitz River. This was done by averaging the damages at each flood level with damages from the preceding level and multiplying that amount by the interval between frequencies of each set of flood events. These frequencies have a probability of occurrence ranging from near annual (.95 probability) to 1-in-500 (.002 probability). The result is a dollar amount of damages which on average, will be incurred in any given year.

Under the no-action condition, the hydrologic characteristics of Cowlitz River will result in constantly changing stage- frequency relationships over time because of continued sediment buildup in the channel. Reduced channel capacity will cause continual changes in the river stages associated with flood events of a given frequency. For example, assuming no-action is taken in the interim, the stage of a 100-year frequency flood at river mile 5.5 in December 1985 is 29.4 feet (NGVD). The corresponding stage of a 100-year flood at river mile 5.5
in 1990 will be 32.0 feet, due to projected sediment infill. This situation is reflected in the stage-frequency relationships with change occurring on a year-to-year basis.

Probability of flood events was determined by watershed characteristics, post-eruption streamflow records, measured channel infill, and sediment deposition projected by a sediment transport model. The projected sediment budget assumes that future annual runoff and river flows will approximate normal water years, in which long-term average runoff conditions prevail.

NED PLAN

Without-Project Condition

No-Action Condition

Under the no-action scenario no additional flood reduction measures would be undertaken in the Cowlitz and Toutle Rivers subsequent to February, 1985. Annual flood damages will increase over time as sediment continues to infill

FIGURE C-1

REACH 5.5 - LONGVIEW
STAGE DAMAGE CURVE

(1985 PRICES)

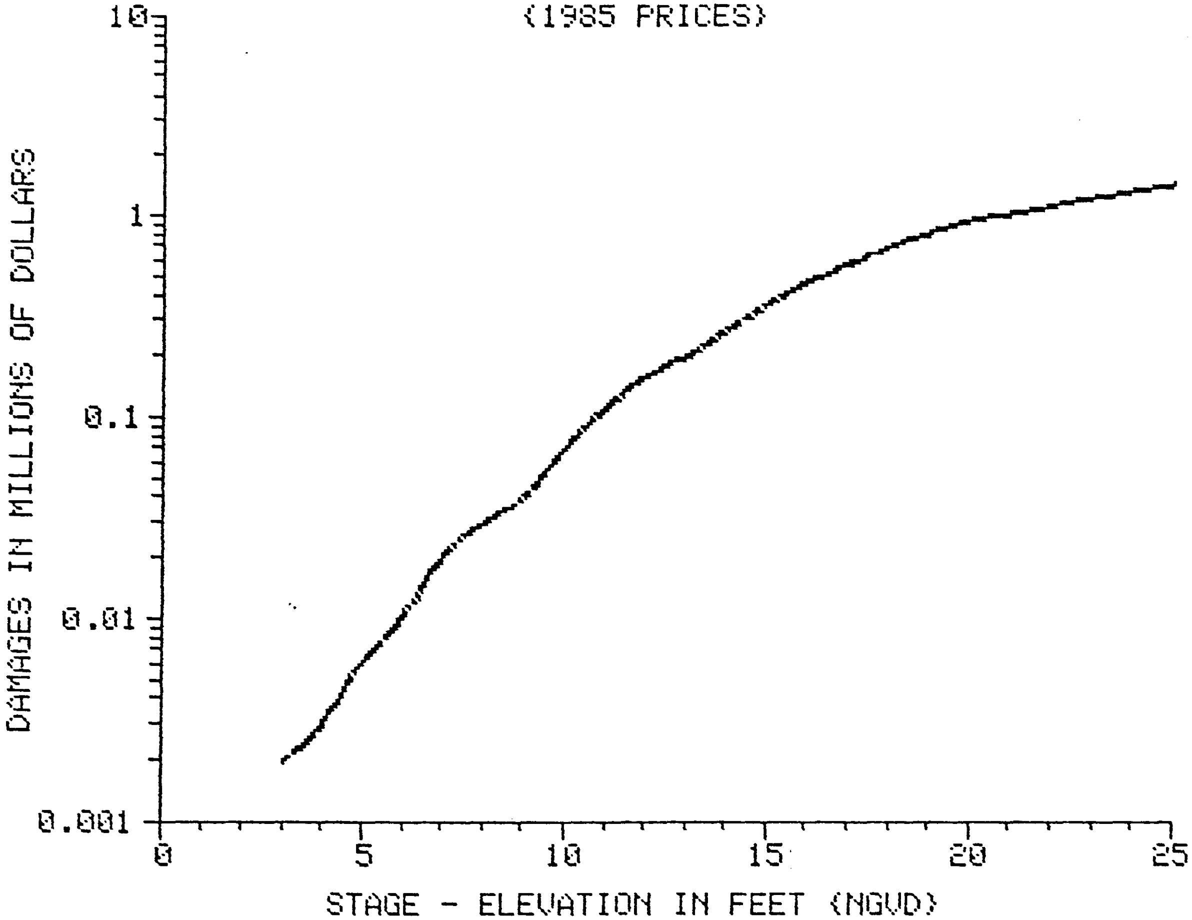


FIGURE C-2

REACH 5.5 - KELSO
STAGE DAMAGE CURVE

(1985 PRICES)

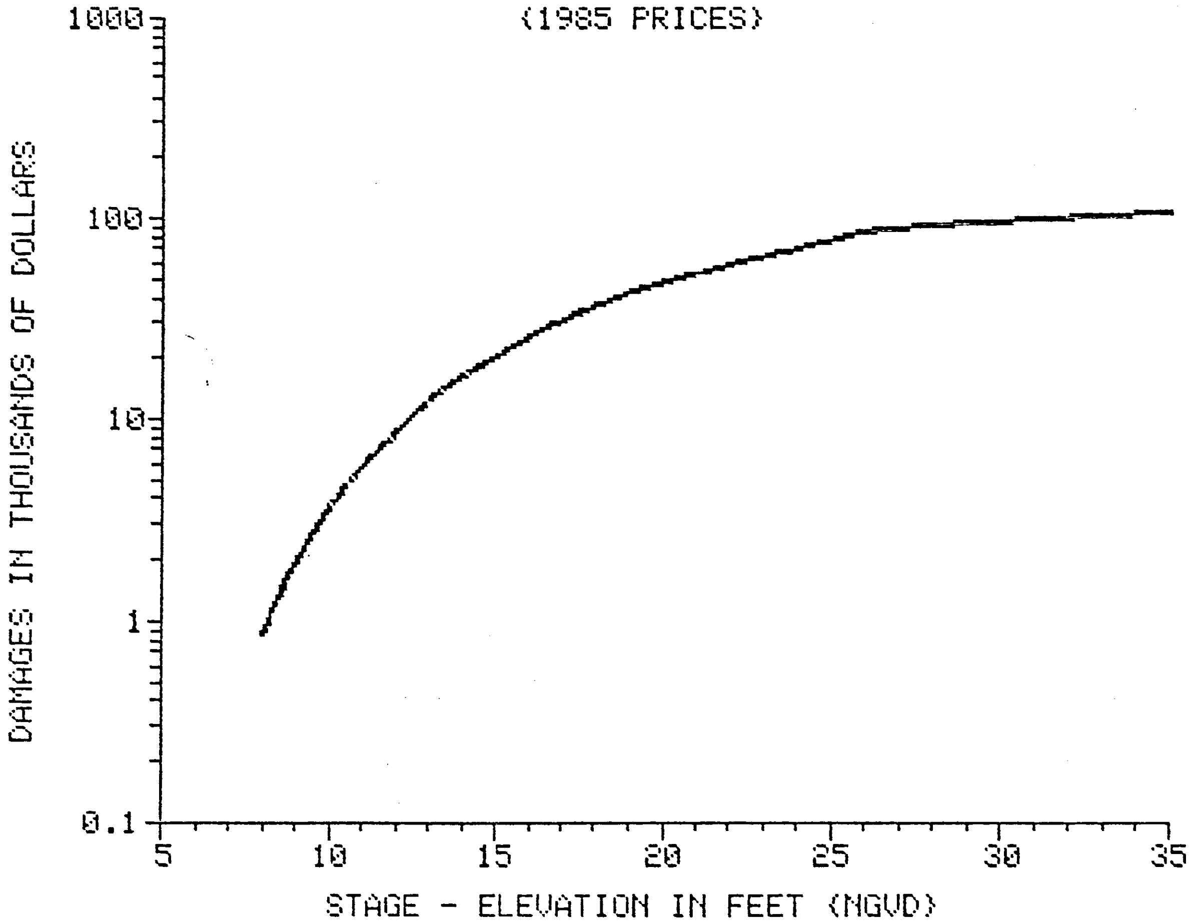


FIGURE C-3

REACH 5.5 - UNLEVEED AREAS
STAGE DAMAGE CURVE

(1985 PRICES)

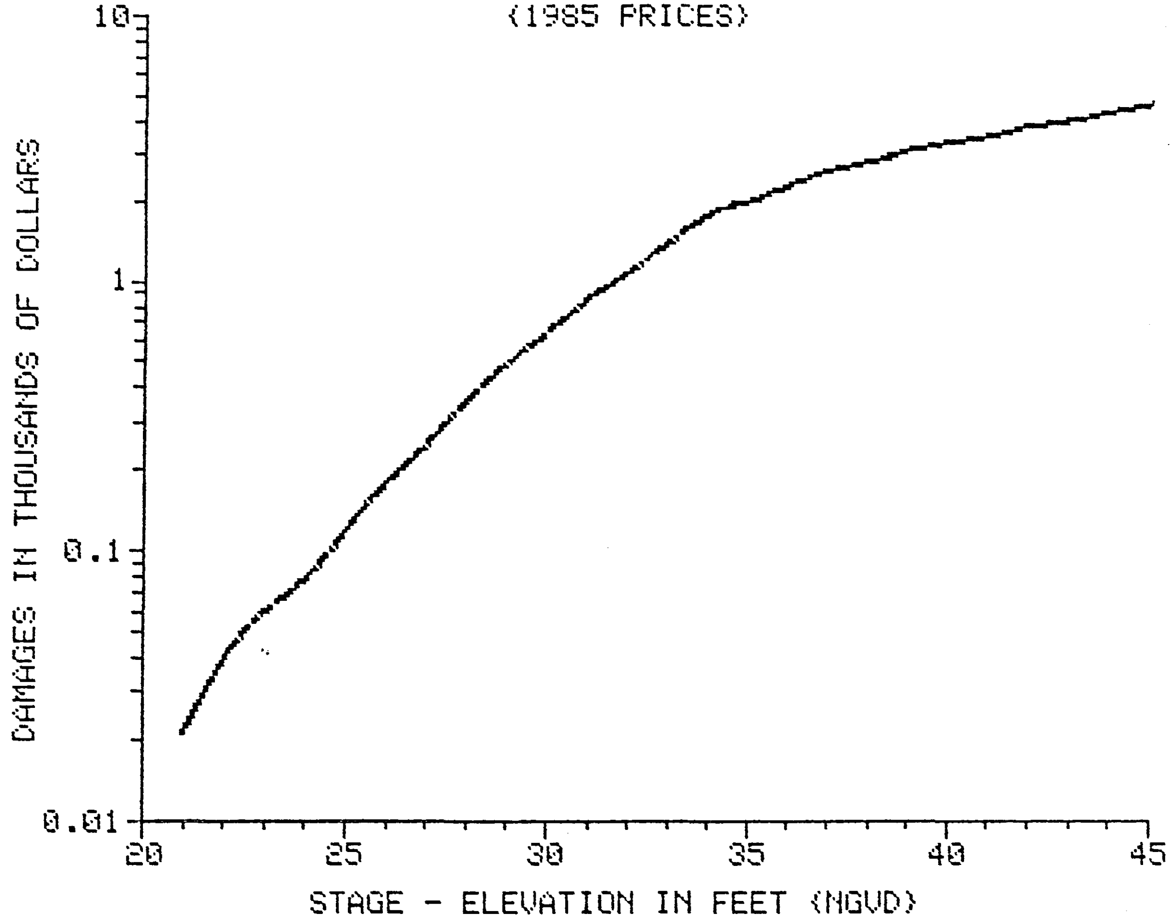
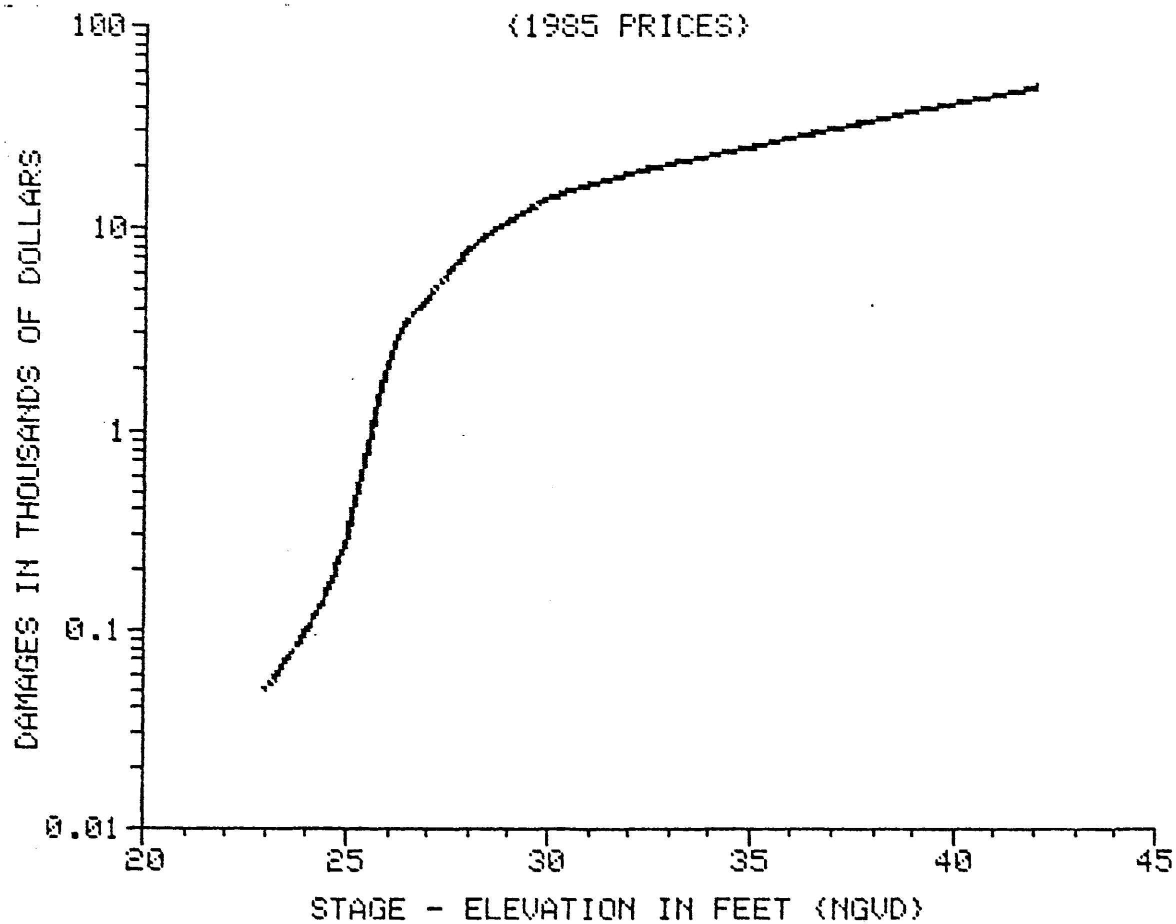


FIGURE C-4

REACH 9.2 - LEXINGTON
STAGE DAMAGE CURVE

(1985 PRICES)



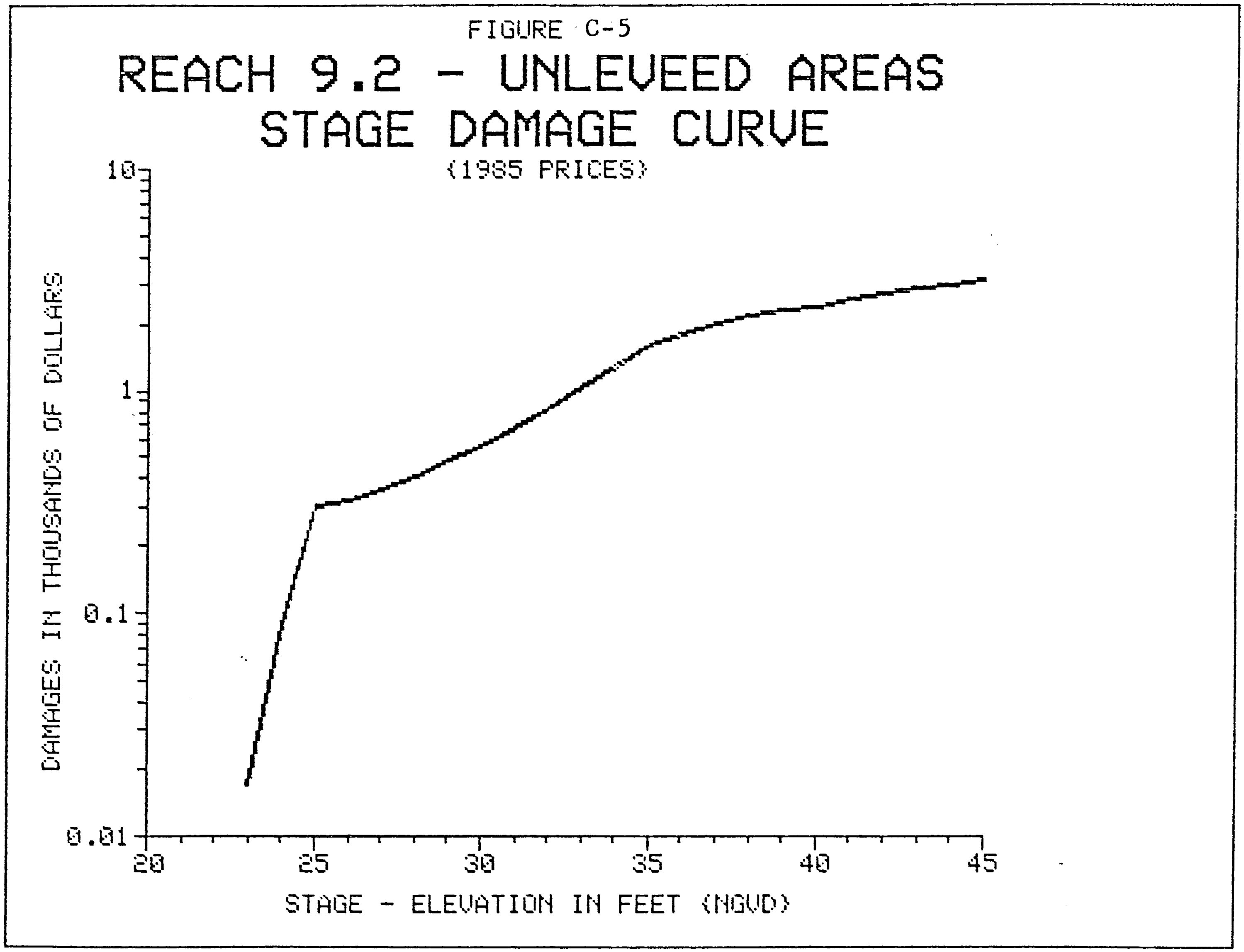


FIGURE C-5
REACH 9.2 - UNLEVEED AREAS
STAGE DAMAGE CURVE
(1985 PRICES)
DAMAGES IN THOUSANDS OF DOLLARS
10
1
0.1
0.01
20
25
30
35
40
45
STAGE - ELEVATION IN FEET (NGVD)

FIGURE C-6

REACH 17.6 - CASTLE ROCK
STAGE DAMAGE CURVE

(1985 PRICES)

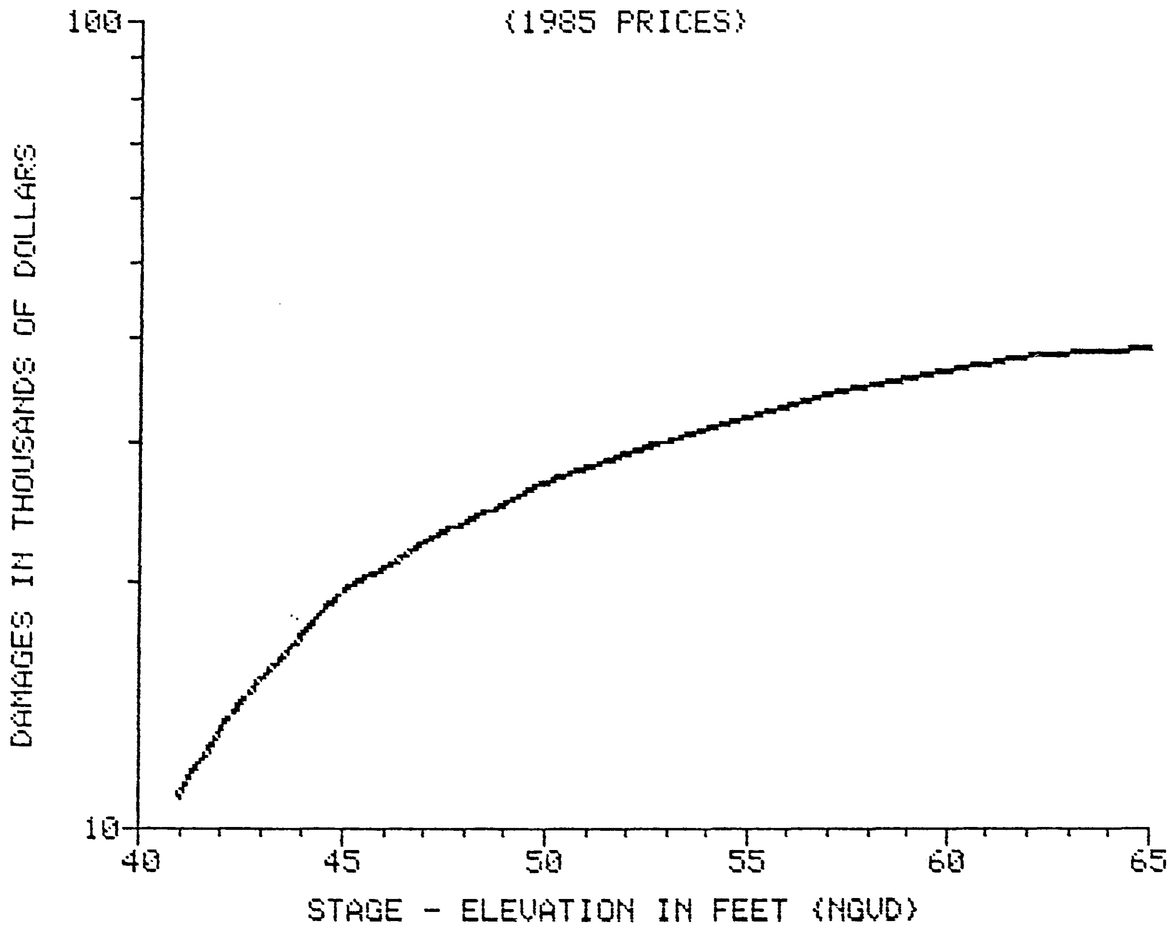


FIGURE C-7

REACH 17.6 - UNLEVEED AREAS
STAGE DAMAGE CURVE

(1985 PRICES)

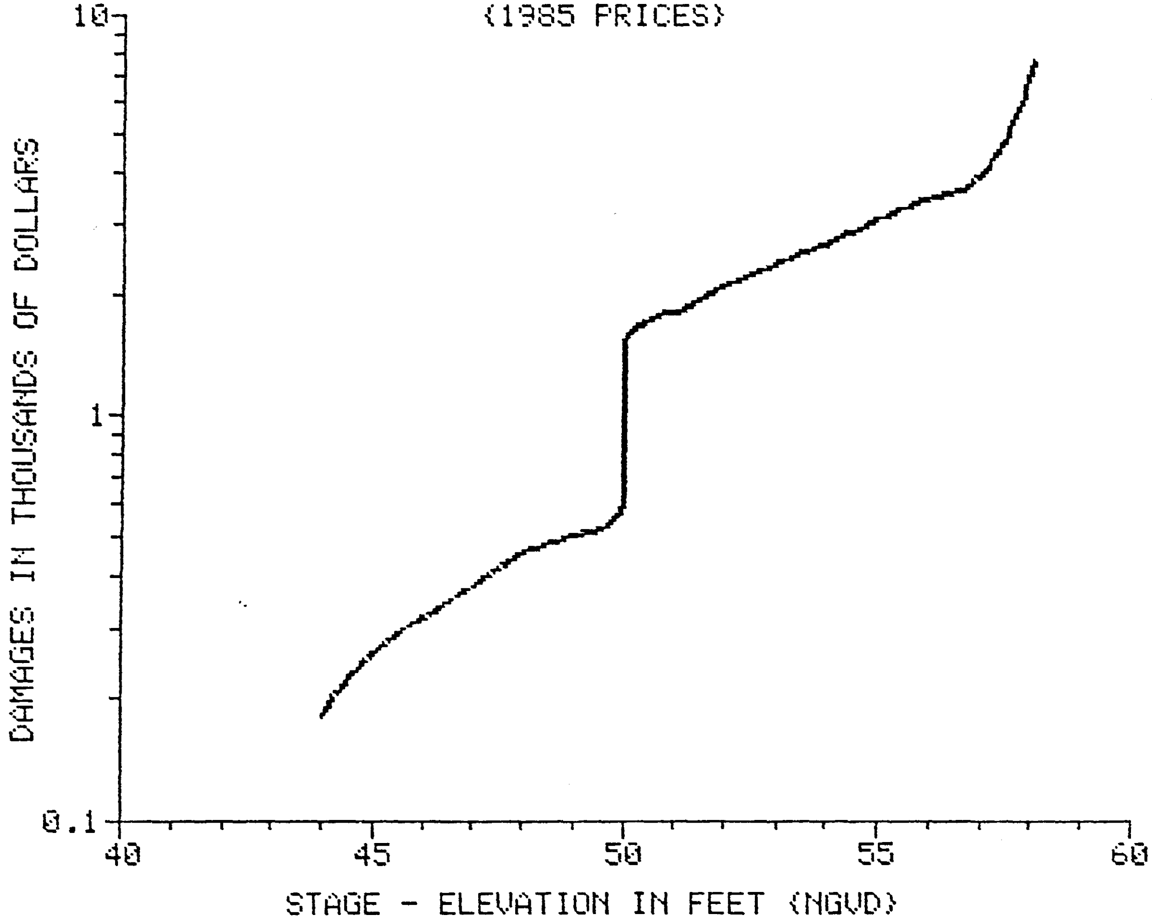
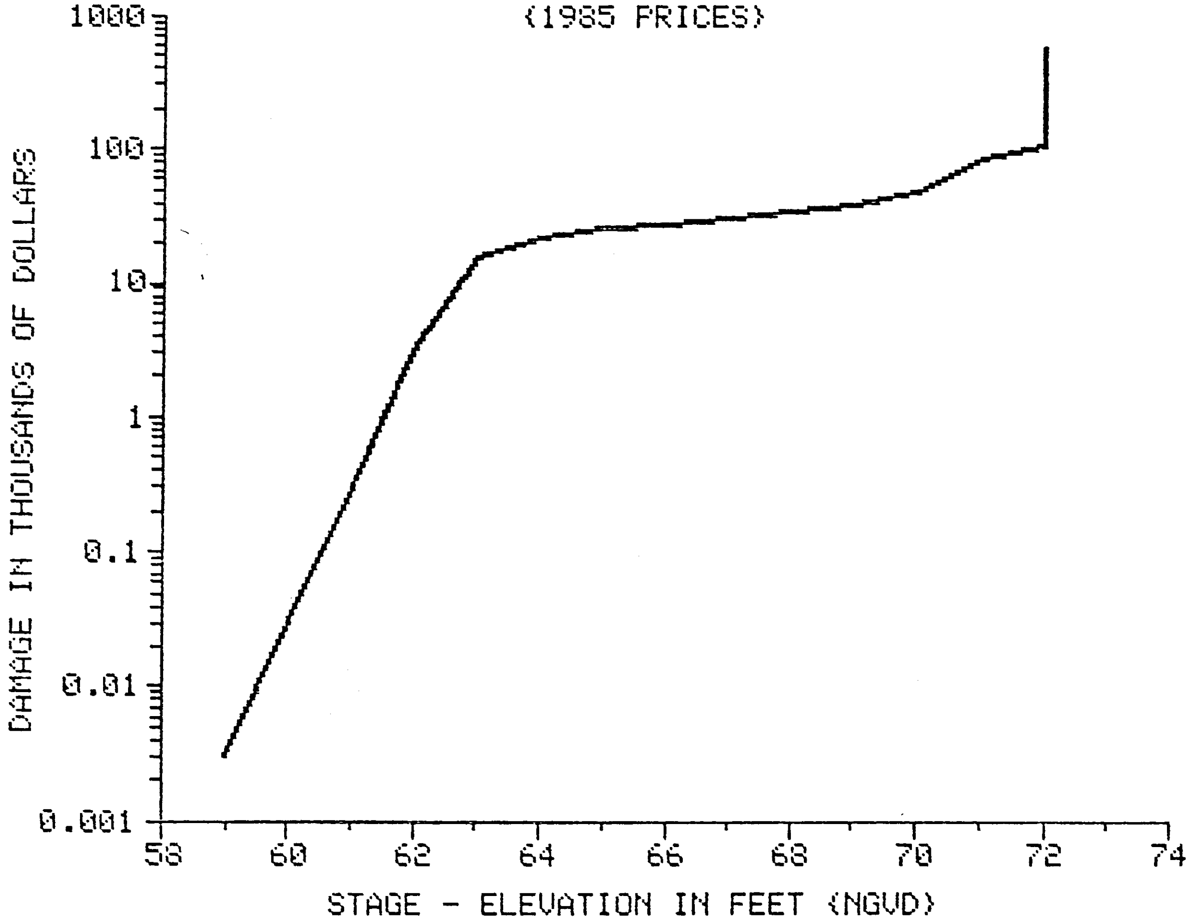


FIGURE C-8

REACH 19.6 - TRANSPORTATION STAGE DAMAGE CURVE

(1985 PRICES)



the river channel. Damage estimates were computed for each successive year until a 2 year event (.50 probability of occurrence) would overtop existing levees. Biennial inundation would dictate abandonment of existing improvements as damages incurred would be equal to or greater than their annualized value. Under these conditions, Kelso would be abandoned in the year 1996, Lexington in 1991, and Castle Rock in 1987. Longview would not be abandoned under the no-action scenario, since a 2-year flood event would not exceed the top of the permanent levee at Longview during the study period. It would, none-the-less, be subject to periodic flooding from less frequent events over the 50 year project life.

Damages to the transportation corridor were not computed beyond 1988. At this point the existing transportation facilities would incur such heavy damages that they would either be abandoned, with traffic being re-routed, or replaced with flood proof structures. Costs incurred for traffic re-routing or replacement of facilities have not been considered beyond 1988 in computing damages under the no-action scenario.

Total average annual damages for the no-action scenario are $43,411,000. This damage estimate is based on sediment quantities and distribution described in Appendix A, and the most recent determination of levee safe heights. This and all other cost and benefit values stated herein are based on an interest rate of 8-5/8% and 1985 price levels. The no-action damage estimate is conservative since only flood damages are considered. Costs associated with abandonment of the flood plain, including loss in real estate value, relocation costs, and impact on the Washington State economy, have not been included. Thus, benefits attributable to maintenance of the base condition are understated.

Base Condition

The base condition for this study is defined as the channel geometry existing in Cowlitz River as established by a hydraulic survey performed in November-December 1983. This channel geometry provides carrying capacity

which affords a level of protection that can be maintained over the long run by annual dredging of sediment infill. These measures were authorized by PL 98-63. The base condition described above represents the without project condition as defined by the Water Resource Council's Principles and Guidelines. It is the condition against which all project alternatives are compared. Cost and residual damage figures for the base condition presented in this document are based on the assumption that the optimum mixture of available dredging options will be employed. Total average annual damages under the base condition are $16,505,000.

Abandonment of portions of the flood plain (a permanent buy-out) was not considered a viable alternative to achieve the base condition since the Corps is legally committed by PL 98-63 to provide flood protection on an interim basis and to protect the occupants of the flood plain to the extent possible. Levee improvements were also not considered as an alternative to sustain the base condition since they would not protect the major transportation facilities or other unleveed areas of the flood plain. These latter measures alone do not meet the base condition criteria.

Justification for Base Condition

Adoption of the previously defined base condition required economic justification of the interim dredging costs incurred for maintaining this condition. Dredging costs and quantities are given in Appendix B. A comparison, over time, between the no-action scenario and the base condition reflects the level of expenditures necessary to maintain a constant (base) level of protection. The difference in flood damages between the no-action and base condition is $26,906,000. This amount represents damage reductions attributable to the maintenance of the base condition. Average annual costs of maintaining the base condition are $13,080,000. Since total reduction of damages is greater than the total cost of achieving them, continued maintenance of the base condition represents both a legal and justifiable activity. The benefit-to-cost ratio for maintenance of the base condition is 2.06-to-1.

The above costs and benefits differ from previous estimates for a variety of reasons. Modifications of the sediment budget and refinements in modeling of sediment movement and deposition patterns have had a major impact. A complete discussion of these changes can be found in Appendix A. Significant sediment infill is not expected to occur in the Columbia River under the present sediment budget and anticipated deposition patterns; therefore no additional costs are anticipated to maintain the Columbia River navigation channel. Levee safe heights at Longview and Kelso have also been refined from previous reports, based upon 1985 surveys of levee condition. Table C-4 summarizes average annual damages for the no-action and base conditions and average annual damage reductions resulting from maintenance of the base condition.

TABLE C-4
AVERAGE ANNUAL DAMAGES
AND DAMAGE REDUCTIONS
NO-ACTION AND BASE CONDITIONS
(000's)

Location	Damages No-Action Condition	Damages Base Condition	Total Damage Reductions
Longview	$ 3,537	$ 180	$ 3,357
Kelso	20,693	13,912	6,781
Lexington	2,645	273	2,372
Castle Rock	1,372	419	953
Unleveed Areas	854	1,589	(735)
Transportation	14,310	132	14,178
Total	$43,411	$16,505	$26,906

With-Project Condition

Description of Alternatives

General: In the Mt. St. Helens Comprehensive Plan (October 1983) five alternative strategies were identified as best suited to deal with the flood threat on the Cowlitz and Toutle Rivers posed by sediment flows from the

eruption of Mt. St. Helens. From this analysis, single retention structure (SRS) alternatives combined with downstream actions were identified for further study. In the Mt. St. Helens Feasibility Report (December 1984), the SRS's were analyzed in greater detail in terms of their costs, benefits, and capabilities, to determine optimum project size and location for this alternative.

As mentioned previously, formulation of the problem has changed somewhat for this decision document. Major refinements have been made to the sediment budget in which the quantity of sediment expected to move down the river system over time has been reduced by about 100 million cubic yards. In addition, the expected distribution of sediment has changed dramatically. For example, sediment infill in the Columbia River, a major source of potential costs in previous reports, is no longer expected to occur. Because of these changes, additional measures have been analyzed for this report in order to insure selection of the most cost effective alternative.

Three basic types of measures were analyzed; dredging, levee improvements, and construction of single and multi-stage SRS. Each of these measures provides flood protection in a different way. Dredging provides flood protection by removing sediment from the river channel and providing added capacity. The levee improvements provide flood protection by increasing the safe level of protection of the existing leveed areas where the majority of damages would occur. Retention structures function by slowing the flow of water in the river channel, this allows the sediment to filter out behind the structure, upstream of the damage susceptible areas.

These measures were combined in various ways to develop project alternatives. A measure is a single, specific action which may or may not solve a problem by itself; a project alternative is a measure or combination of measures, which will address the problem. The following alternatives were analyzed: dredging, levee improvements with a base level of dredging, levee improvements with an increased level of dredging, SRS's with supplemental dredging, and SRS's combined with levee improvements and supplemental dredging. A more detailed discussion of these alternatives follows, including a listing of average

annual damages, damage reductions, costs, net benefits, and benefit-to-cost ratios for each alternative. Finally, a summary review of the alternatives is included and selection of the NED plan, based on the principle of maximum net benefits, is discussed.

Dredging Alternatives: Three dredging alternatives were evaluated. The first was the base condition, which has been described previously. This is the minimum level of dredging which is required given the Corps legal commitment to provide a nominal level of protection. A maximum dredging alternative was analyzed which provides the greatest level of flood protection attainable by dredging measures alone. An intermediate level of dredging was also evaluated in order to identify the most cost effective dredging plan. The following table presents the level of protection provided by each dredging alternative for each leveed area.

TABLE C-5
LEVEL OF PROTECTION
DREDGING ALTERNATIVES
(recurrence interval in years)

Base Condition	Toutle River (1985-2000)	Cowlitz River (2001-2035)
Longview	71	71
Kelso	3	3
Lexington	77	59
Castle Rock	71	20

Intermediate Dredging	Toutle River (1985-1997)	Cowlitz River (1998-2035)
Longview	167	149
Kelso	11	10
Lexington	167	143
Castle Rock	118	63

Maximum Dredging	Toutle River (1985-1997)	Cowlitz River (1998-2035)
Longview	303	270
Kelso	56	50
Lexington	313	263
Castle Rock	200	117

Water surface elevations vary, as do levels of protection, depending on whether dredging is accomplished in the Toutle River or in the Cowlitz River. Dredging in the Toutle River is generally less expensive than in the Cowlitz River due to the proximity of disposal areas. Therefore, dredging required by any alternative would initially be undertaken in the Toutle. When disposal areas adjacent to the Toutle are filled, dredging activity would shift to the Cowlitz River. It is estimated that disposal areas in the Toutle basin would be filled by the year 2000 for the base condition and 1997 for intermediate and maximum dredging options. Average annual damages and damage reductions for the dredging alternatives, measured against the base condition, are listed in Table C-6.

Net benefits for a particular dredging alternative are calculated by comparing the reduction in flood damages attributable to that plan, relative to the base, with the additional cost of providing that level of dredging over and above the cost of maintaining the base. Maintenance of the base condition through dredging is estimated to cost $13,080,000 annually. The intermediate level of dredging would have an average annual cost of $16,500,000, or $3,420,000 more than base level dredging. Average annual costs of a maximum dredging effort are $22,080,000, an increase of $9,000,000 over the base level.

Average annual damage reductions for the intermediate dredging option, compared to the base, are $11,332,000. Average annual net benefits for this alternative are $7,912,000. Damage reductions and net benefits for the maximum dredging option are $15,202,000 and $6,202,000 respectively, in average annual terms.

<u>Levee Improvements</u>: Three levee improvement alternatives were analyzed in conjunction with dredging to maintain base channel geometry. These three combinations are referred to as minimal, medium, and high levee improvements.

TABLE C-6
AVERAGE ANNUAL DAMAGES AND DAMAGE REDUCTIONS
DREDGING ALTERNATIVES
(000's)

Intermediate Dredging

Location	Damages Base Condition	Damages Intermediate Dredging	Total Damage Reductions
Longview	$ 180	$ 28	$ 152
Kelso	13,912	3,895	10,017
Lexington	273	100	173
Castle Rock	419	195	224
Unleveed Areas	1,589	888	701
Transportation	132	67	65
Total	$16,505	$ 5,173	$11,332

Maximum Dredging

Location	Damages Base Condition	Damages Maximum Dredging	Total Damage Reductions
Longview	$ 180	$ 4	$ 176
Kelso	13,912	727	13,185
Lexington	273	31	242
Castle Rock	419	89	330
Unleveed Areas	1,589	417	1,172
Transportation	132	35	97
Total	$16,505	$ 1,303	$15,202

They were analyzed for the leveed areas of Longview, Kelso, Lexington, and Castle Rock. Levee improvements at each of the leveed areas are considered separate projects and were analyzed independently, as well as in combination. The base level of protection would be maintained in each case. This would provide some protection to unleveed areas and to transportation facilities since these areas would not benefit from levee improvements.

Minimal levee improvements amount to raising low spots and/or minor strengthening of the existing levees to bring them up to Corps standards. Minimal levee improvements would be in place in 1987. The existing levee at Longview meets Corps standards, therefore minimal levee improvements were not evaluated for this area. Construction of medium or high levees would require significant increases in the height and breath of existing levees. Medium and high levee raises would be in place in 1988; however, for these alternatives, protection equivalent to that of minimal levee improvements would be provided at Kelso in 1987 due to the significant benefit of providing protection there as soon as possible. Average annual damages and damage reductions for levee improvements measured against the base condition, are shown in Table C-7.

TABLE C-7
AVERAGE ANNUAL DAMAGES AND DAMAGE REDUCTIONS
LEVEE IMPROVEMENTS
(000's)

Minimal Levee Improvements

Location	Damages Base Condition	Damages Minimal Levee	Total Damage Reductions
Longview	$ 180	$ 180	$ 0
Kelso	13,912	1,846	12,066
Lexington	273	165	108
Castle Rock	419	282	137
Unleveed Areas	1,589	1,589	0
Transportation	132	132	0
Total (Kl only)	$16,505	$ 4,439	$12,066
Total (Kl & Lx)	$16,505	$ 4,331	$12,174
Total (Kl & CR)	$16,505	$ 4,302	$12,203
Total (Kl Lx & CR)	$16,505	$ 4,194	$12,311

Medium Levee Improvements

Location	Damages Base Condition	Damages Medium Levee	Total Damage Reductions
Longview	$ 180	$ 114	$ 66
Kelso	13,912	1,441	12,471
Lexington	273	81	192
Castle Rock	419	133	286
Unleveed Areas	1,589	1,589	0
Transportation	132	132	0
Total (Kl Lx & CR)	$16,505	$ 3,490	$13,015

High Levee Improvements

Location	Damages Base Condition	Damages High Levee	Total Damage Reductions
Longview	$ 180	$ 28	$ 152
Kelso	13,912	1,223	12,689
Lexington	273	39	234
Castle Rock	419	40	379
Unleveed Areas	1,589	1,589	0
Transportation	132	132	0
Total (Kl Lx & CR)	$16,505	$ 3,051	$13,454

The average annual costs associated with each levee improvement option are shown in Table C-8.

TABLE C-8
AVERAGE ANNUAL COSTS
LEVEE IMPROVEMENTS
(000's)

Location	Minimal	Medium	High
Longview	N.A.	$ 2,270	$ 2,630
Kelso	$ 140	1,390	1,930
Lexington	100	350	520
Castle Rock	30	270	380

Table C-9 displays benefits, costs, net benefits and benefit-to-cost ratios for minimal levee improvements, and both medium and high levee raises at each location.

As independent measures, minimal levee improvement options are justified at Kelso, Lexington, and Castle Rock. Average annual net benefits for minimal levees are $11,926,000 for Kelso, $8,000 for Lexington, and $107,000 for Castle Rock. The construction of these three levees in combination yields maximum net benefits for the dredging option with levee raises. Since minimal levee improvements provide the maximum net benefits at Kelso, Lexington, and Castle Rock, construction of levees providing medium and high protection is not indicated at these locations.

For example, at Kelso, a medium levee raise provides net benefits of $11,081,000 and a high levee raise provides net benefits of $10,759,000. Both of these values are less than the $11,926,000 provided by minimal levee improvements, thus the additional benefits attributable to larger levees are more than offset by increased costs. No levee improvements are justified at Longview because the cost of these levees exceeds the benefits that would result from their construction.

TABLE C-9
AVERAGE ANNUAL NET BENEFITS AND B/C RATIOS
LEVEE IMPROVEMENTS
(dollars in thousands)

Alternative	Benefits	Costs	Net Benefits	B/C Ratios
Minimal Levee Improvements				
at Longview	N.A.	N.A.	N.A.	N.A.
at Kelso	$12,066	$140	$11,926	86.19 to 1
at Lexington	$108	$100	$8	1.08 to 1
at Castle Rock	$137	$30	$107	4.57 to 1
Combinations of Minimal Levees				
at Kl & Lx	$12,174	$240	$11,934	50.73 to 1
at Kl & CR	$12,203	$170	$12,033	71.78 to 1
at Kl Lx & CR	$12,311	$270	$12,041	45.60 to 1
Medium Levee Raises				
at Longview	$66	$2,270	($2,204)	0.03 to 1
at Kelso	$12,471	$1,390	$11,081	8.97 to 1
at Lexington	$192	$350	($158)	0.55 to 1
at Castle Rock	$286	$270	$16	1.06 to 1
High Levee Raises				
at Longview	$152	$2,630	($2,478)	0.06 to 1
at Kelso	$12,689	$1,930	$10,759	6.57 to 1
at Lexington	$234	$520	($286)	0.45 to 1
at Castle Rock	$379	$380	($1)	1.00 to 1

Intermediate Dredging with Minimal Levee Improvements: Four minimal levee combinations were evaluated in conjunction with intermediate levels of dredging. These included: (1) intermediate dredging with minimal levee improvements at Kelso only, (2) at Kelso and Lexington, (3) at Kelso and Castle Rock, and (4) at Kelso, Lexington and Castle Rock. The components of these alternatives have been discussed previously in this report. Minimal levee improvements at Kelso were reviewed in each alternative because they were justified individually by a wide margin. Table C-10 lists levels of protection at the leveed areas for the intermediate dredging option with minimal levee improvements.

TABLE C-10
INTERMEDIATE DREDGING WITH MINIMAL LEVEE IMPROVEMENTS
LEVELS OF PROTECTION
(recurrence interval in years)

Location	Toutle Dredging	Cowlitz Dredging
Longview 1/	167	149
Kelso	143	139
Lexington	233	192
Castle Rock	133	71

1/ Protection at Longview is the result of intermediate dredging only; no minimal levee is included for this location.

Table C-11 lists average annual damages for the base condition and dredging/levee alternatives, and average annual damage reductions attributable to each.

TABLE C-11
AVERAGE ANNUAL DAMAGES AND DAMAGE REDUCTIONS
INTERMEDIATE DREDGING WITH MINIMAL LEVEES
(000's)

Location	Damages Base Condition	Damages for Dredging Plus Levees	Total Damage Reductions
Longview	$ 180	$ 28	$ 152
Kelso	13,912	565	13,347
Lexington	273	59	214
Castle Rock	419	183	236
Unleveed Areas	1,589	888	701
Transportation	132	67	65
Total (Kl only)	$16,505	$ 1,843	$14,662
Total (Kl & Lx)	$16,505	$ 1,802	$14,703
Total (Kl & CR)	$16,505	$ 1,831	$14,674
Total (Kl Lx & CR)	$16,505	$ 1,790	$14,715

Table C-12 displays benefits, costs, net benefits, and benefit-to-cost ratios for the intermediate dredging with minimal levee improvement alternatives.

TABLE C-12
AVERAGE ANNUAL NET BENEFITS AND B/C RATIOS
INTERMEDIATE DREDGING WITH MINIMAL LEVEES
(dollars in thousands)

Alternative	Benefits	Costs	Net Benefits	B/C Ratios
Kelso only	$14,662	$3,560	$11,102	4.12 to 1
Kl & Lx	14,703	3,660	11,043	4.02 to 1
Kl & CR	14,674	3,590	11,084	4.09 to 1
Kl Lx & CR	14,715	3,690	11,025	3.99 to 1

The project that provides intermediate dredging and minimal levee improvements at Kelso only is the optimum project evaluated from this group. It provides net benefits of $11,102,000.

Single Retention Structures: A single retention structure (SRS) functions by slowing the flow of water in the river channel and allowing sediment to filter out. Sediment not trapped behind the SRS must be removed from the channel at a downstream site. Each SRS option, in combination with some level of supplemental dredging, was designed to provide approximately the same level of protection as base dredging. In fact, the SRS options provide somewhat greater protection. An SRS may be constructed as a single unit, or as a multi-stage project. It would be situated on the upper Toutle River near its confluence with Green River. This site was selected in previous studies.

For the single stage SRS, five spillway heights, in combination with supplemental dredging, were evaluated. These spillway heights are 50, 100, 125, 150, and 200 feet. Four multi-staged SRS alternatives, in combination with supplemental dredging, were also evaluated. These are as follows:

(I) A 100 foot MSRS designed to function as the base for a 125 foot structure.

(II) A 100 foot MSRS designed to function as the base for a 125 foot structure, with an additional 12.5 foot structure to be added when required. Total height of this structure is 112.5 feet.

(III) A 100 foot MSRS designed to function as the base for a 125 foot structure, with two additional 12.5 foot structures to be added when required. Total height of this structure is 125 feet.

(IV) A 100 foot MSRS designed to function as the base for a 125 foot structure, with an additional 25 foot structure to be added when required. Total height of this structure is 125 feet.

All single stage SRS options are planned to be operational in 1987, as are the first stages of the multi-stage alternatives. Timing for construction of additional stages would depend on the rate of sedimentation experienced.

Since the amount of sediment retained varies depending on the height of the SRS, material that is not retained by the structure must be removed from the river channel at a location downstream from the SRS. With small structures, larger amounts of material must be removed downstream, conversely, with large structures, less material will require dredging. Costs will vary with structure size and amount of dredging required. Supplemental dredging would be accomplished primarily in the Cowlitz River. All nine single and multi-stage SRS alternatives, in combination with varying levels of supplemental dredging, provide the same level of flood protection and prevent the same amount of average annual damages. Table C-13 lists levels of protection provided at each location by the SRS alternatives.

TABLE C-13
LEVELS OF PROTECTION PROVIDED BY SRS ALTERNATIVES
(recurrence interval in years)

Location	SRS Level of Protection
Longview	100
Kelso	4
Lexington	91
Castle Rock	71

Table C-14 presents average annual damages and damage reductions for the SRS alternatives relative to the base condition.

TABLE C-14
AVERAGE ANNUAL DAMAGES AND DAMAGE REDUCTIONS
SRS ALTERNATIVES
(000's)

Location	Base Damages	Damages with SRS	Damage Reductions
Longview	$ 180	$ 124	$ 56
Kelso	13,912	10,222	3,690
Lexington	273	227	46
Castle Rock	419	234	185
Unleveed Areas	1,589	1,488	101
Transportation	132	97	35
Total	$16,505	$12,392	$ 4,113

In addition to average annual damage reductions of $4,113,000 for flood control, an SRS, when in place, eliminates dredging which would otherwise be necessary to maintain the base condition. This amounts to a $13,080,000 annual cost savings. Therefore, total average annual benefits for each SRS alternative are $17,193,000. Table C-15 presents benefits, costs, net benefits and benefit-to-cost ratios for the SRS alternatives.

TABLE C-15
SINGLE RETENTION STRUCTURE ALTERNATIVES
AVERAGE ANNUAL NET BEBEFITS AND B/C RATIOS
(dollars in thousands)

Alternative	Damage Reductions	Dredging Savings	Benefits	Costs	Net Benefits	B/C Ratios
Single Stage						
50 ft.	$ 4,113	$13,080	$17,193	$11,790	$ 5,403	1.46 to 1
100 ft.	4,113	13,080	17,193	8,760	8,433	1.96 to 1
125 ft	4,113	13,080	17,193	8,150	9,043	2.11 to 1
150 ft.	4,113	13,080	17,193	8,700	8,493	1.98 to 1
200 ft.	4,113	13,080	17,193	11,250	5,943	1.53 to 1

TABLE C-15 (continued)

Alternative	Damage Reductions	Dredging Savings	Benefits	Costs	Net Benefits	B/C Ratios
Multi-Stage						
I	$ 4,113	$13,080	$17,193	$ 9,160	$ 8,033	1.88 to 1
II	4,113	13,080	17,193	8,980	8,213	1.91 to 1
III	4,113	13,080	17,193	8,610	8,583	2.00 to 1
IV	4,113	13,080	17,193	8,450	8,743	2.03 to 1

The optimal single stage SRS is the 125 foot high structure. This structure has average annual net benefits of $9,043,000. The optimal multi-stage SRS is alternative four which is 100 feet high initially, with a second 25 foot increment to be added in 1997. This alternative has net benefits of $8,743,000. Based on this evaluation, the single stage SRS provides greater net benefits than an equivalent SRS constructed in increments.

SRS with Minimal Levee Improvements: A group of alternatives were analyzed which combine an SRS with minimal levee improvements. Four alternatives were evaluated: the first evaluates an SRS with minimal levee improvements at Kelso only, the second includes minimal levee improvements at Kelso and Lexington, the third includes minimal levee improvements at Kelso and Castle Rock, and the fourth, minimal levee improvements at Kelso, Lexington, and Castle Rock. The 125 foot single stage SRS, identified in the preceeding section, was used for this evaluation. The minimal levee improvements at Kelso were included in each alternative because these improvements are justified by a wide margin when analyzed separately.

These alternatives increase the level of protection at each of the leveed areas when compared to levels of protection offered by the SRS alone. The level of protection at Kelso increases from 4 year protection to 77 year protection, Lexington increases from 91 year to 133 year protection, and Castle Rock increases from 71 year to 91 year protection. The level of

protection for Longview and the unleveed areas remains the same as that provided by the SRS only. Table C-16 lists average annual damages and damage reductions relative to the base for each of these alternatives.

TABLE C-16
SRS WITH MINIMAL LEVEE IMPROVEMENTS
AVERAGE ANNUAL DAMAGES AND DAMAGE REDUCTIONS
($000's)

Alternative	Base Damages	Damages SRS + Levees	Damage Reductions
Longview	$ 180	$ 124	$ 56
Kelso	13,912	1,699	12,213
Lexington	273	151	122
Castle Rock	419	192	227
Unleveed Areas	1,589	1,488	101
Transportation	132	97	35
Kelso Only	$16,505	$ 3,869	$12,636
Kl & Lx	$16,505	3,793	12,712
Kl & CR	$16,505	3,827	12,678
Kl Lx & CR	$16,505	3,751	12,754

In addition to the average annual damage reductions presented in the previous table, these alternatives also eliminate the need to dredge to maintain the base condition. This is a cost saving of $13,080,000 annually.

The average annual cost for each alternative can be calculated by summing the average annual cost of the 125 foot single stage SRS ($8,150,000) with the average annual cost of the applicable minimal levee improvements ($140,000 at Kelso, $100,000 at Lexington, and $30,000 at Castle Rock). Thus the cost of

the first alternative (SRS + Kelso only) is \$8,290,000, the cost of the second alternative (SRS + Kelso + Lexington) is \$8,390,000, the cost of the third alternative (SRS + Kelso + Castle Rock) is \$8,320,000, and the cost of the fourth alternative (SRS + Kelso + Lexington + Castle Rock) is \$8,420,000. Benefits, costs, net benefits and B/C ratios for these four alternatives are provided in Table C-17.

TABLE C-17
SRS WITH MINIMAL LEVEE IMPROVEMENTS
AVERAGE ANNUAL NET BENEFITS AND B/C RATIOS
(dollars in thousands)

Alternative	Damage Reductions	Cost Savings	Benefits	Costs	Net Benefits	B/C Ratios
Kelso only	\$12,636	\$13,080	\$25,716	\$8,290	\$17,426	3.10 to 1
Kl & Lx	\$12,712	\$13,080	\$25,792	\$8,390	\$17,402	3.07 to 1
Kl & CR	\$12,678	\$13,080	\$25,758	\$8,320	\$17,438	3.10 to 1
Kl Lx & CR	\$12,754	\$13,080	\$25,834	\$8,420	\$17,414	3.07 to 1

The alternative with the greatest net benefits from this group is that which provides for an SRS with minimal levee improvements at Kelso and Castle Rock. This alternative has benefits of \$25,758,000, costs of \$8,320,000, and net benefits of \$17,438,000.

SRS with Base-Plus Dredging: An alternative was analyzed that combines an SRS with dredging protection that exceeds base. This level of protection will be referred to as "base-plus" in this document. Unlike the SRS alternatives evaluated previously in this report, this alternative was designed to provide levels of protection similar to the intermediate dredging plan rather than base level dredging. The 125 foot SRS, identified in the preceeding section, was used for this evaluation. Table C-18 displays levels of protection for the SRS with base-plus dredging alternative.

TABLE C-18
LEVELS OF PROTECTION
SRS WITH BASE-PLUS DREDGING
(recurrence interval in years)

Base-Plus Dredging	Toutle River
Longview	167
Kelso	11
Lexington	167
Castle Rock	118

Table C-19 lists average annual damages and damage reductions for the SRS with base-plus dredging.

TABLE C-19
AVERAGE ANNUAL DAMAGES AND DAMAGE REDUCTIONS
SRS WITH BASE-PLUS DREDGING ALTERNATIVE
(000's)

Location	Damages Base Condition	Damages SRS and Base-Plus Dredging	Total Damage Reductions
Longview	$ 180	$ 28	$ 152
Kelso	13,912	3,895	10,017
Lexington	273	100	173
Castle Rock	419	195	224
Unleveed Areas	1,589	888	701
Transportation	132	67	65
Total	$16,505	$ 5,173	$11,332

In addition to the average annual damage reductions presented in the preceeding table, this alternative also eliminates the need to dredge to maintain the base condition. This is a cost saving of $13,080,000 annually, for a total benefit of $24,412,000. The average annual cost for the SRS with base-plus dredging alternative is $9,240,000. Thus net benefits for this alternative are $15,172,000 and the benefit-to-cost ratio is 2.64 to 1.

SRS with Base-Plus Dredging and Minimal Levee Improvements: Four minimal levee improvement options were evaluated with the SRS and base-plus dredging alternative: the first includes minimal levee improvements at Kelso only, the second considers minimal levee improvements at Kelso and Lexington, the third includes minimal levee improvements at Kelso and Castle Rock, and the fourth, minimal levee improvements at Kelso, Lexington, and Castle Rock. The minimal levee improvements at Kelso were included in each alternative because these improvements are justified by a wide margin when analyzed separately.

These alternatives increase the level of protection at each of the leveed areas when compared to the SRS with base-plus dredging alone. The level of protection at Longview stays at 167 year protection, Kelso increases from 11 year protection to 143 year protection, Lexington increases from 167 year to 233 year protection, and Castle Rock increases from 118 year to 133 year protection. Table C-20 gives average annual damages and damage reductions relative to the base for each of these alternatives.

Table C-20
SRS WITH BASE-PLUS DREDGING AND
MINIMAL LEVEE IMPROVEMENTS
AVERAGE ANNUAL DAMAGES AND DAMAGE REDUCTIONS
(000's)

Location	Damages Base Condition	Damages for SRS, Dredging and Levees	Total Damage Reductions
Longview	$ 180	$ 28	$ 152
Kelso	13,912	565	13,347
Lexington	273	59	214
Castle Rock	419	183	236
Unleveed Areas	1,589	888	701
Transportation	132	67	65
Total (Kl only)	$16,505	$ 1,843	$14,662
Total (Kl & Lx)	$16,505	$ 1,802	$14,703
Total (Kl & CR)	$16,505	$ 1,831	$14,674
Total (Kl Lx & CR)	$16,505	$ 1,790	$14,715

In addition to the average annual damage reductions presented in the previous table, these alternatives also eliminate the need to dredge to maintain the base condition. This is a cost saving of $13,080,000 annually.

The average annual cost for each alternative is the sum of the average annual cost of the SRS with base-plus dredging ($9,240,000) and the average annual cost of the applicable minimal levee improvements ($140,000 at Kelso, $100,000 at Lexington, and $30,000 at Castle Rock). Thus the cost of the first alternative (Kelso only) is $9,380,000, the cost of the second alternative (Kelso + Lexington) is $9,480,000, the cost of the third alternative (Kelso + Castle Rock) is $9,410,000, and the cost of the fourth alternative (Kelso + Lexington + Castle Rock) is $9,510,000. Benefits, costs, net benefits and B/C ratios for these four alternatives are provided in Table C-21.

TABLE C-21
SRS WITH BASE-PLUS DREDGING AND
MINIMAL LEVEE IMPROVEMENTS
Average Annual Net Benefits and B/C Ratios
(dollars in thousands)

Alternative	Damage Reductions	Cost Savings	Benefits	Costs	Net Benefits	B/C Ratios
Kelso only	$14,662	$13,080	$27,742	$ 9,380	$18,362	2.96 to 1
Kl & Lx	$14,703	$13,080	$27,783	$ 9,480	$18,303	2.93 to 1
Kl & CR	$14,674	$13,080	$27,754	$ 9,410	$18,344	2.95 to 1
Kl Lx & CR	$14,715	$13,080	$27,795	$ 9,510	$18,285	2.92 to 1

The alternative with the greatest net benefits is that which provides for an SRS with base-plus dredging and minimal levee improvements at Kelso only. This alternative yields $18,362,000 in net benefits and is the optimal project from this group.

NED Plan

Identification of the NED plan is based on the principle of maximum net benefits as required by Corps of Engineers guidance. Net benefits are defined as the difference between total benefits and total costs. Benefits, costs, net benefits and benefit-to-cost ratios for each of the project alternatives are presented in Table C-22.

TABLE C-22
COWLITZ - TOUTLE PROJECT ALTERNATIVES
AVERAGE ANNUAL NET BENEFITS AND B/C RATIOS
(dollars in thousands)

Alternative	Benefits	Costs	Net Benefits	B/C Ratios
Intermediate Dredging				
	$11,332	$3,420	$7,912	3.31 to 1
Maximum Dredging				
	$15,202	$9,000	$6,202	1.69 to 1
Minimal Levee Improvements				
at Kelso	$12,066	$140	$11,926	86.19 to 1
at Lexington	$108	$100	$8	1.08 to 1
at Castle Rock	$137	$30	$107	4.57 to 1
Combinations of Minimal Levees				
at Kl & Lx	$12,174	$240	$11,934	51.73 to 1
at Kl & CR	$12,203	$170	$12,033	71.78 to 1
at Kl Lx & CR	$12,311	$270	$12,041	45.60 to 1
Medium Levee Raises				
at Longview	$66	$2,270	($2,204)	0.03 to 1
at Kelso	$11,631	$1,250	$10,381	9.30 to 1
at Lexington	$192	$350	($158)	0.55 to 1
at Castle Rock	$286	$270	$16	1.06 to 1
High Levee Raises				
at Longview	$152	$2,630	($2,478)	0.06 to 1
at Kelso	$11,848	$1,790	$10,058	6.62 to 1
at Lexington	$234	$520	($286)	0.45 to 1
at Castle Rock	$379	$380	($1)	1.00 to 1
Intermediate Dredging + Minimal Levee				
at Kelso only	$14,662	$3,560	$11,102	4.12 to 1
at Kl & Lx	$14,703	$3,660	$11,043	4.02 to 1
at Kl & CR	$14,674	$3,590	$11,084	4.09 to 1
at Kl Lx & CR	$14,715	$3,690	$11,025	3.99 to 1
Single Stage SRS 1/				
	$17,193	$8,150	$9,043	2.11 to 1
Multi-Stage SRS 1/				
	$17,193	$8,450	$8,743	2.03 to 1
SRS + Minimal Levees 1/				
at Kelso only	$25,716	$8,290	$17,426	3.10 to 1
at Kl & Lx	$25,792	$8,390	$17,402	3.07 to 1
at Kl & CR	$25,758	$8,320	$17,438	3.10 to 1
at Kl Lx & CR	$25,834	$8,420	$17,414	3.07 to 1
SRS + Base-Plus Dredging + Minimal Levees 1/				
at Kelso only	$27,742	$9,380	$18,362*	2.96 to 1
at Kl & Lx	$27,783	$9,480	$18,303	2.93 to 1
at Kl & CR	$27,754	$9,410	$18,344	2.95 to 1
at Kl Lx & CR	$27,795	$9,510	$18,285	2.92 to 1

* Maximum net benefits.

1/ Includes $13,080,000 in benefits due to elimination of costs to maintain the base condition.

Conclusion: The NED plan is the SRS with base-plus dredging and minimal levee improvements at Kelso only. It has benefits of $27,742,000, costs of $9,380,000, and net benefits of $18,362,000. The benefit-to-cost ratio for this project is 2.96 to 1. Further studies will be conducted to determine if additional increases in SRS height can be more cost effective than downstream dredging after the SRS has reached capacity (i.e. filled with sediment). Preliminary studies indicate that under the expected sediment budget, the addition of two 25 foot stages, timed appropriately, would further reduce total project costs.

Incremental Justification: The NED plan must be viewed as a system which includes several measures. Each element of the NED plan must be incrementally justified (i.e. the incremental benefits derived from implementing each measure must be greater than the additional costs of that measure). The SRS with base level dredging is justified more than 2-to-1 over the base condition. It provides benefits of $17,193,000, costs of $8,150,000, and net benefits of $9,043,000. The addition of base-plus dredging to this plan increases benefits by $7,219,000 at an additional cost of $1,090,000 for an increase in net benefits of $6,129,000. The addition of minimal levee improvements at Kelso adds incremental average annual benefits of $3,330,000 at an additional average annual cost of $140,000 for an increase in average annual net benefits of $3,190,000.

It should be noted that the minimal levee improvements at Castle Rock and Lexington, which are justified if constructed separately, are not justified under the NED plan. This is because construction of an SRS coupled with incremental dredging provides enough additional protection at these sites to eliminate the justification for minimal levee improvements. Under the NED plan, the addition of minimal levee improvements at Castle Rock provides an increase in benefits of $12,000, but at a cost of $30,000, for a reduction in net benefits of $18,000. The addition of minimal levee improvements at Lexington would provide an increase in average annual benefits of $41,000, but at an average annual cost of $100,000, for a reduction in average annual net benefits of $59,000.

Comparison to No-Action: Thus far in this document all alternatives have been compared to the base condition, which is the without project condition in the absence of further action by the Federal Government. In this section, the most cost effective dredging, single stage, and multi-stage SRS alternatives are compared to the no-action condition. This is done to demonstrate that the NED plan would remain the same even if "no-action" was considered to be the without project condition. A comparison was made between the no-action condition and the base condition with minimal levee improvements at Kelso, Lexington, and Castle Rock, the intermediate dredging alternative with minimal levee improvements at Kelso only, the 125 foot SRS alternative with base plus dredging and minimal levee improvements at Kelso only (the NED plan), and the 125 foot MSRS with base level dredging and minimal levee improvements at Kelso and Castle Rock.

Damages under the no-action condition are $43,411,000. The base dredging alternative with minimal levee improvements at Kelso, Lexington and Castle Rock has residual damages of $4,194,000. The intermediate dredging alternative with minimal levee improvements at Kelso only has residual damages of $1,843,000. The single stage SRS with base-plus dredging and minimal levee improvements at Kelso only also has residual damages of $1,843,000. The MSRS, with minimal levee improvements at Kelso and Castle Rock, has residual damages of $3,827,000. Table C-23 lists damage reductions, costs, net benefits, and B/C ratios for these four alternatives when compared to no-action.

Based on the principle of maximum net benefits, the SRS alternative with base-plus dredging and minimal levee improvements at Kelso (the NED plan) is optimal when compared to the no-action scenario. This alternative has net benefits of $32,188,000 and a benefit-to-cost ratio of 4.43 to 1.

SENSITIVITY OF NED PLAN TO VARIATIONS IN SEDIMENT BUDGET

General

A level of uncertainty exists in projecting future conditions. This section addresses the most critical future projection in the decision document, the sediment budget, testing the NED plan, and two dredging alternatives, against variations in sediment projections.

TABLE C-23
COMPARISON OF ALTERNATIVES
TO THE NO-ACTION CONDITION
(dollars in thousands)

Alternative	Damage Reductions	Costs	Net Benefits	B/C Ratios
Base w/ 3 Levees	$39,217	$13,350	$25,867	2.94 to 1
Intermediate w/ 1 Levee	$41,568	$16,640	$24,928	2.50 to 1
SRS w/ Base Plus & 1 Levee	$41,568	$ 9,380	$32,188	4.43 to 1
MSRS w/ 2 Levees	$39,584	$ 8,620	$30,964	4.59 to 1

Methodology

The details of the estimated sediment budget (hereafter depicted as E) have been discussed previously in this report. The E budget is the current estimate of future sediment movement. Over 550 mcy are expected to be deposited in the Cowlitz and Toutle Rivers during the next 50 years. For comparative purposes, this sensitivity analysis looks at two other sediment projections that represent one-half the sediment budget (1/2 E) and 1-1/2 times the sediment budget (1-1/2 E).

This section examines the consequences for a chosen alternative when anticipating one budget and actually incurring a greater or lesser one. These effects are measured in terms of the average annual costs associated with construction of an alternative and the average annual residual damages expected to occur if that alternative is implemented. Together these costs represent the total costs incurred by society for implementation of a particular alternative.

A description is included of residual average annual flood damages and the costs of the SRS at Green River with base plus ddg SRS alternative for each sediment budget are \$1.84 million. They do not vary with changes in the sediment budget since excess sediment would be dredged from the river channel downstream from the SRS.

If a budget different from E were anticipated, the best SRS plan would then be at a different height than 125 feet. If 1/2 E is expected, the SRS plan with the lowest costs to society would be an SRS of 100 feet with base-plus dredging and minimal levee improvements at Kelso only, while an SRS of 150 feet with base-plus dredging and minimal levee improvements at Kelso only would be the least cost plan for an expected budget of 1-1/2 E. Total plan costs vary with different actual budgets because of downstream action costs. With the E sediment budget, the AAC of the 100 foot SRS alternative would be \$10.55 million, with 1/2 E these costs decline to \$7.81, and with 1-1/2 E these costs increase to \$17.17 million. The AAC of the 150 foot SRS with the same level of dredging and levee improvements would be \$9.80 million for the E sediment budget, \$8.90 million for the 1/2 E budget, and \$13.99 million for the 1-1/2 E budget.

Costs and Flood Damages for the Dredging Alternatives

Dredging represents a flexible method for dealing with different sediment levels as initial fixed costs are held lower. As different levels of sediment migrate through the river system, they are dealt with to the extent practicable. For the E sediment budget, the intermediate dredging alternative provides residual damages similar to the NED plan. The AAC of this dredging alternative, including the cost of the minimal levee improvements at Kelso, is \$5.35 million for the 1/2 E budget, \$16.64 million for the E budget, and \$26.20 million for the 1-1/2 E budget. The AAC of the base dredging alternative is \$4.16 million for 1/2 E, \$13.35 million for E, and \$19.27 million for 1-1/2 E.

For the dredging alternatives, different levels of sediment deposition in the Cowlitz River associated with 1/2 E and 1-1/2 E will result in different residual average annual flood damages (AAD) than those shown for the E

budget. The AAD for the intermediate dredging alternative with the 1/2 E budget are $1.63 million, with E damages are $1.84 million, and with 1-1/2 E they are $2.43 million. With the E sediment budget, this alternative provides residual damages equal to those of the NED plan. The AAD with the base dredging alternative are $3.86 million for the 1/2 E budget, $4.19 million for the E budget, and $4.68 million for the 1-1/2 E budget. The intermediate dredging alternative is the most cost-effective dredging alternative for the 1/2 E sediment budget; the base dredging alternative is the most cost-effective dredging alternative for the E and 1-1/2 E sediment budgets.

Comparison of Dredging and SRS

Table C-24 presents the results of the sensitivity analysis. This matrix shows nine possible combinations of structure design and sediment budget, and the resulting costs and damages of incurring one of these budgets. Each block in Table C-24 compares the total costs to society (AAD plus AAC) for the SRS alternative, including the NED plan, and the two dredging alternatives. By comparing the sum of AAC and AAD in each block, the total cost incurred by society for adopting a particular alternative can be identified, given a particular sediment budget.

In all cases, if the 1/2 E budget actually occurs, the intermediate dredging alternative is the least costly plan. It saves $2.67 million over the 100 foot SRS option ($9.65-$6.98 million), $2.75 million over the 125 foot SRS option ($9.73-$6.98 million), $3.76 million over the 150 foot SRS option ($10.74-$6.98 million), and $1.04 million over the base dredging alternative ($8.02-$6.98 million).

If the E or 1-1/2 E budgets actually occur, the most cost-effective plan is an SRS alternative. If the E budget actually occurs, the 125 foot SRS alternative is the most cost-effective plan. It saves $6.32 million over the base dredging plan ($17.54-$11.22 million) and $7.26 million over the intermediate dredging alternative ($18.48-$11.22 million). If the 1-1/2 E budget actually occurs, the 150 foot SRS is the least costly plan. It saves $9.96 million over the base dredging alternative ($23.95-$13.99 million) and $14.64 million over the intermediate dredging alternative ($28.63-$13.99 million).

Table C-24
Sensitivity Matrix
Average Annual Costs plus Average Annual Damages
(in millions of dollars)

Actual Budget	Design for: SRS @ 100 ft. 1/2 E		SRS @ 125 ft. E		SRS @ 150 ft. 1-1/2 E	
1/2 E	SRS-AAC	7.67	SRS-AAC	7.75	SRS-AAC	8.76
	1 Levee-AAC	0.14	1 Levee-AAC	0.14	1 Levee-AAC	0.14
	AAD	1.84	AAD	1.84	AAD	1.84
	Total	9.65	Total	9.73	Total	10.74
	Int Drg-AAC	5.21	Int Drg-AAC	5.21	Int Drg-AAC	5.21
	1 Levee-AAC	0.14	1 Levee-AAC	0.14	1 Levee-AAC	0.14
	AAD	1.63	AAD	1.63	AAD	1.63
	Total	6.98	Total	6.98	Total	6.98
	Base Drg-AAC	3.89	Base Drg-AAC	3.89	Base Drg-AAC	3.89
	3 Levees-AAC	0.27	3 Levees-AAC	0.27	3 Levees-AAC	0.27
	AAD	3.86	AAD	3.86	AAD	3.86
	Total	8.02	Total	8.02	Total	8.02
E	SRS-AAC	10.41	SRS-AAC	9.24	SRS-AAC	9.66
	1 Levee-AAC	0.14	1 Levee-AAC	0.14	1 Levee-AAC	0.14
	AAD	1.84	AAD	1.84	AAD	1.84
	Total	12.39	Total	11.22	Total	11.64
	Int Drg-AAC	16.50	Int Drg-AAC	16.50	Int Drg-AAC	16.50
	1 Levee-AAC	0.14	1 Levee-AAC	0.14	1 Levee-AAC	0.14
	AAD	1.84	AAD	1.84	AAD	1.84
	Total	18.48	Total	18.48	Total	18.48
	Base Drg-AAC	13.08	Base Drg-AAC	13.08	Base Drg-AAC	13.08
	3 Levees-AAC	0.27	3 Levees-AAC	0.27	3 Levees-AAC	0.27
	AAD	4.19	AAD	4.19	AAD	4.19
	Total	17.54	Total	17.54	Total	17.54
1-1/2 E	SRS-AAC	17.03	SRS-AAC	12.93	SRS-AAC	12.01
	1 Levee-AAC	0.14	1 Levee-AAC	0.14	1 Levee-AAC	0.14
	AAD	1.84	AAD	1.84	AAD	1.84
	Total	19.01	Total	14.91	Total	13.99
	Int Drg-AAC	26.06	Int Drg-AAC	26.06	Int Drg-AAC	26.06
	1 Levee-AAC	0.14	1 Levee-AAC	0.14	1 Levee-AAC	0.14
	AAD	2.43	AAD	2.43	AAD	2.43
	Total	28.63	Total	28.63	Total	28.63
	Base Drg-AAC	19.00	Base Drg-AAC	19.00	Base Drg-AAC	19.00
	3 Levees-AAC	0.27	3 Levees-AAC	0.27	3 Levees-AAC	0.27
	AAD	4.68	AAD	4.68	AAD	4.68
	Total	23.95	Total	23.95	Total	23.95

Since the estimate of sediment movement is E, the following discussion examines the consequences of designing for this budget. If a 125 foot SRS is constructed in anticipation of the E budget and only 1/2 E occurs then society would incur an additional cost of $2.75 million over the most cost-effective dredging alternative (intermediate dredging). If an E budget actually occurs then society would save $6.32 million over the most cost-effective dredging option (base dredging). If the 1-1/2 E budget occurs then savings over base dredging would be $9.04 million in terms of AAC + AAD.

If 1/2 the E budget is expected, then the most cost-effective alternative is intermediate dredging. Assuming this budget actually occurs, the intermediate dredging alternative would save $1.04 million in AAC + AAD over the base dredging alternative and $2.67 million over the 100 foot SRS alternative. If the 1/2 E budget was expected and the E budget actually occurred, the intermediate dredging alternative would cost society $.94 million more than the base dredging alternative and $6.09 million more than the 100 foot SRS alternative. If the 1/2 E budget were expected and the 1-1/2 E budget actually occurred, the intermediate dredging would cost society $4.68 million more than the base dredging alternative and $9.62 million more than the 100 foot SRS alternative.

If the 1-1/2 E budget is expected, a 150 foot SRS is the most cost-effective alternative. Assuming the 1-1/2 E budget actually occurs, the 150 foot SRS alternative has $9.96 million less in AAC + AAD than the base dredging alternative and $14.64 million less in AAC + AAD than the intermediate dredging alternative. If 1-1/2 E is expected and E actually occurs, the 150 foot SRS alternative would provide savings of $5.90 million over the base dredging alternative and $6.84 million over the intermediate dredging alternative. If the 1-1/2 E sediment budget were expected and the 1/2 E budget actually occurred, the 150 foot SRS would cost society $2.72 million more than the base dredging alternative and $3.76 million more than the intermediate dredging option.

The break even point for the percentage of the sediment budget that would have to occur to produce the same costs for the most cost-effective dredging alternatives and SRS alternatives is shown on Figures C-9 through C-11 for each design scenario. Figure C-10 shows that if the 125-foot SRS option were built, it would have lower costs and damages than the most cost-effective

dredging alternative as long as .64 E, or a volume in excess of .64 E occurs. Figures C-9 and C-11 display the same information for the 100 foot SRS option (.65 E) and 150 foot SRS option (.68 E) respectively. Figure C-12 shows that if the optimal SRS plan is chosen for a given sediment load, the SRS will be preferable to the most cost-effective dredging alternative as long as sediment volume in excess of .63 E occurs.

Conclusion of the Sediment Budget Sensitivity Analysis

If the NED plan discussed in this report were implemented in anticipation of the E budget, and 1/2 E actually occurs, then the least costly alternative was not chosen. However, if the NED plan were built and .64 E or sediment in excess of 64 E occurs, then the NED plan represents a less costly alternative than long-term dredging.

RISK ANALYSIS - EXTREME EVENTS

General

The first component of the sensitivity analysis demonstrated the relative advantages of the Green River SRS and two dredging alternatives for different levels of sediment movement. The sensitivity analysis concentrated on each plan's effectiveness in dealing with projected average annual movement of sediment. As explained in Appendix A, actual movement of sediment over time is expected to vary widely from the average annual condition. The remainder of this sensitivity section describes the risks associated with events generating greater than average sediment movements. Two alternatives are evaluated, the SRS with base plus dredging and minimal levee improvements at Kelso only (referred to as the "SRS alternative" in this section), and base dredging with minimal levee improvements at Kelso, Lexington, and Castle Rock (referred to as the "dredging alternative" in this section).

Since it is impossible to predict the timing of non-typical hydrologic events, they are not included in the evaluation process. This section demonstrates that the dredging option is more sensitive than the NED plan to extreme sediment transport events and their associated risks of increased flood damages. Selection of the best plan must consider risks associated with large atypical events.

FIGURE C-9

SENSITIVITY OF ALTERNATIVES DESIGN FOR 1/2 E

(1985 PRICES)

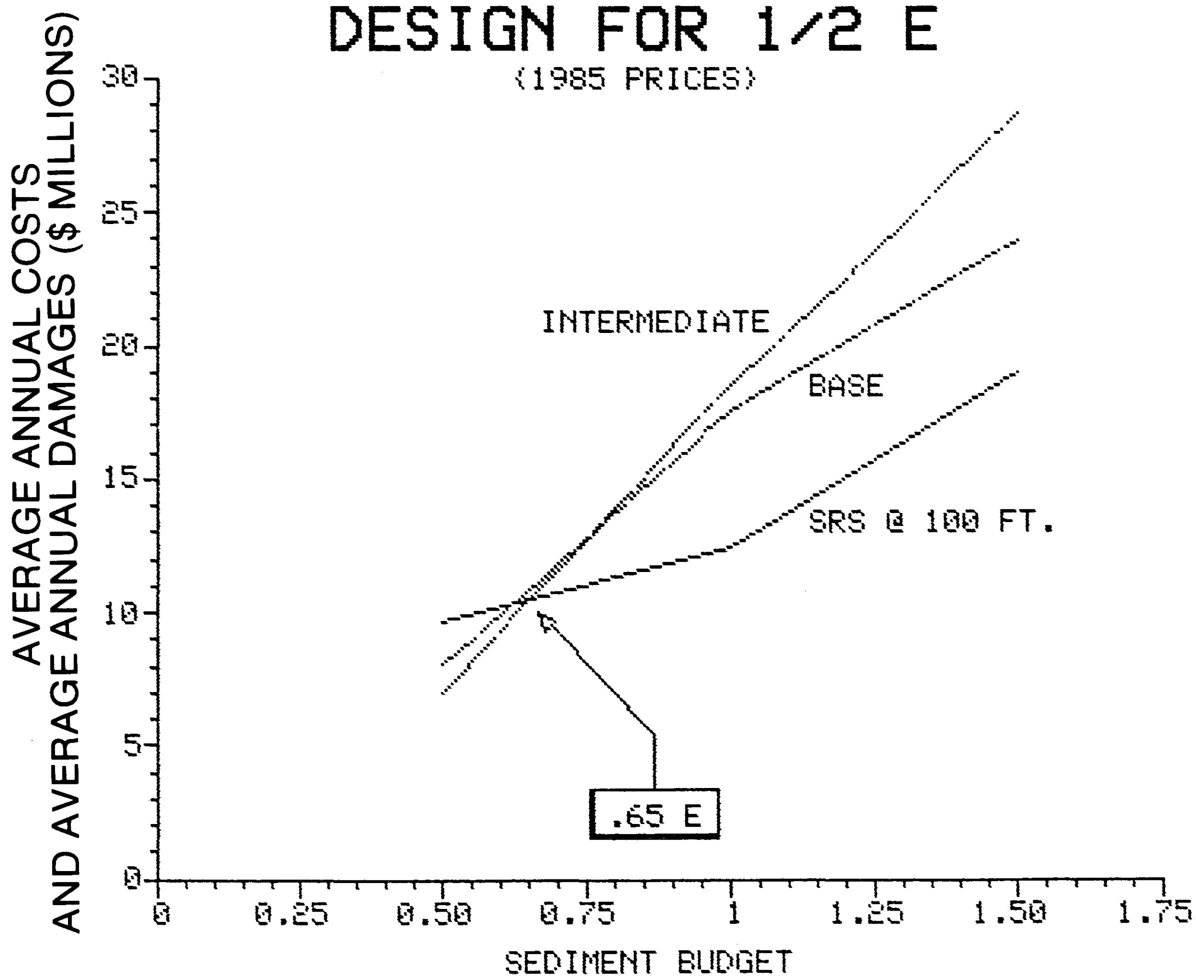


FIGURE C-10

SENSITIVITY OF ALTERNATIVES DESIGN FOR E

(1985 PRICES)

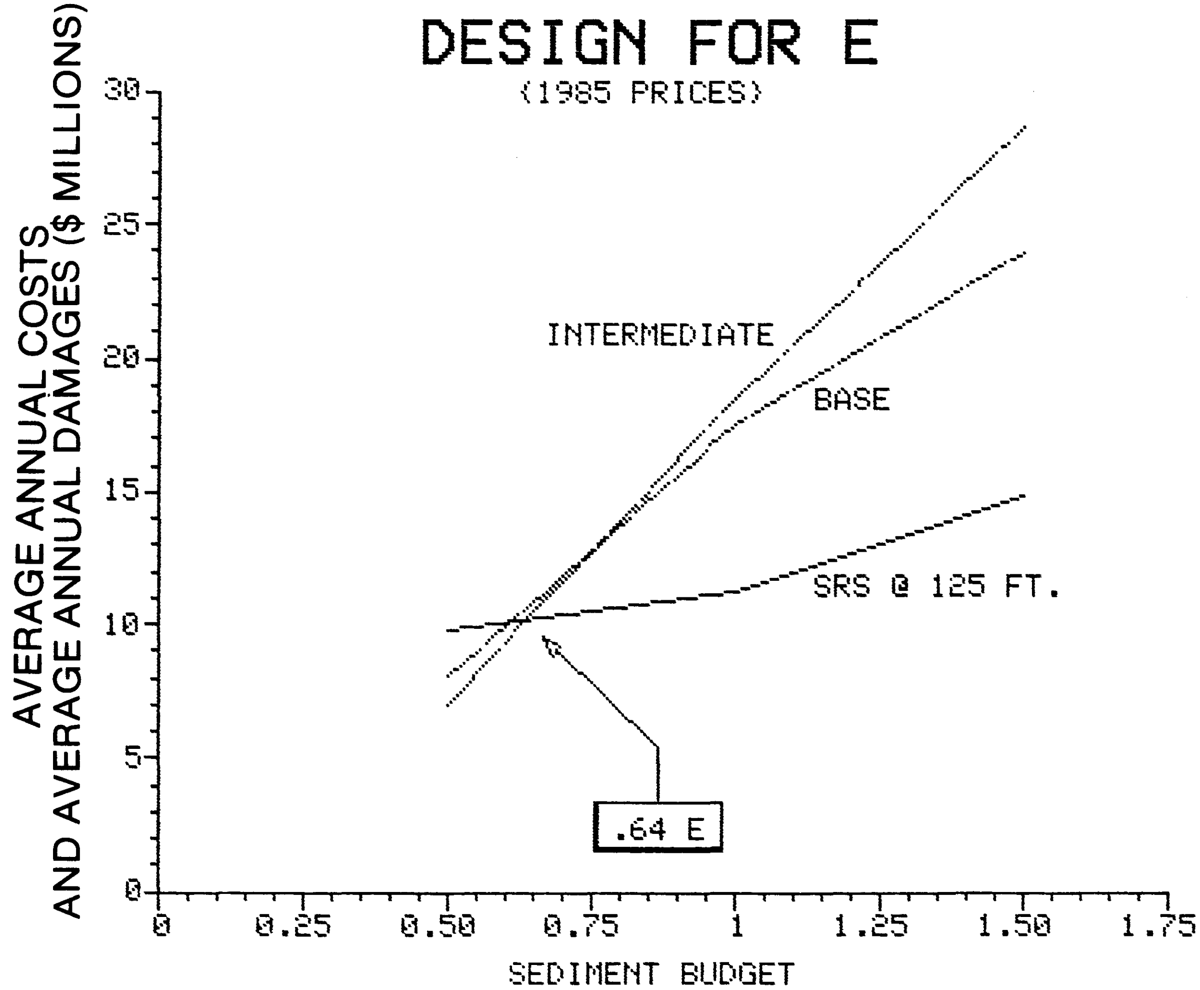


FIGURE C-11

SENSITIVITY OF ALTERNATIVES
DESIGN FOR 1-1/2 E

(1985 PRICES)

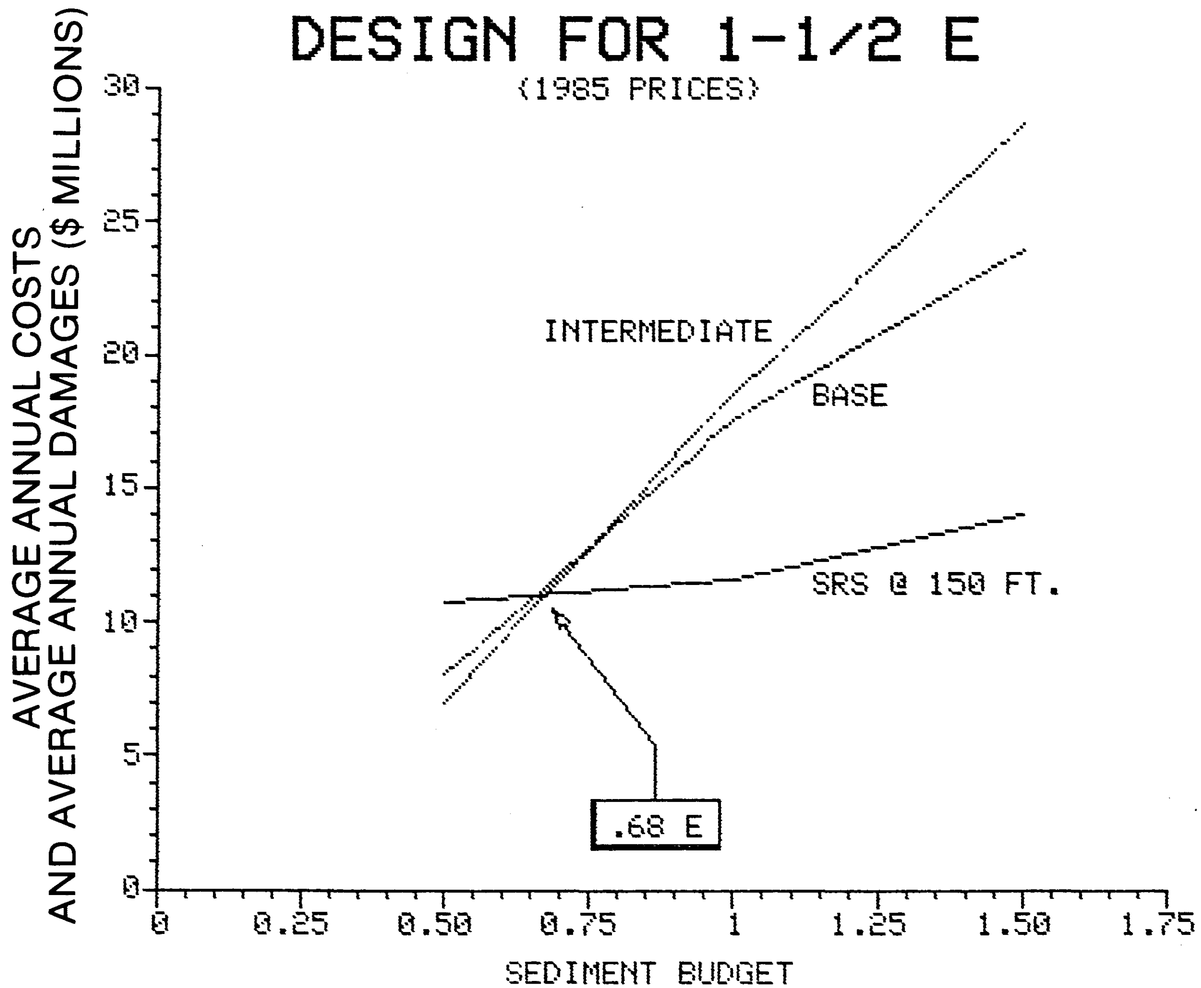
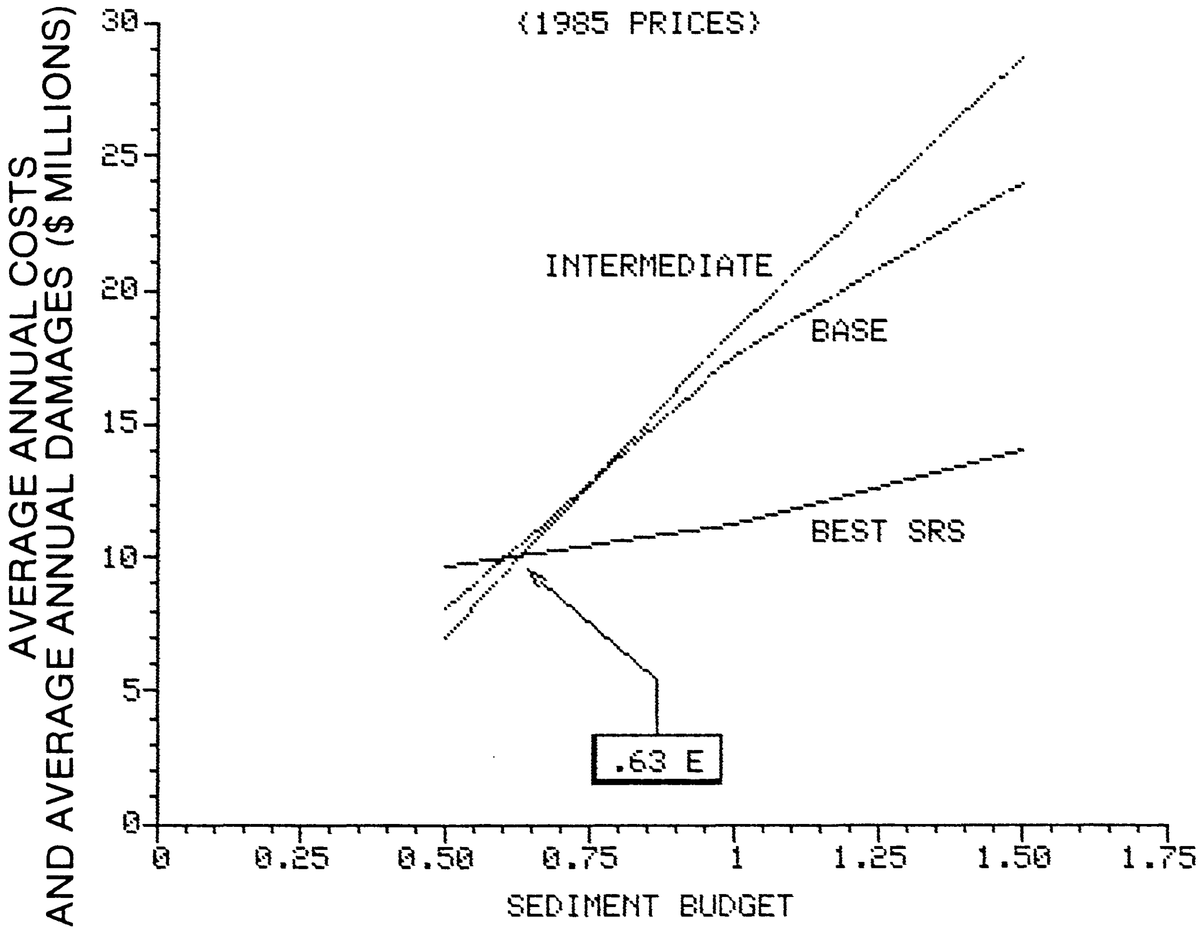


FIGURE C-12

SENSITIVITY OF ALTERNATIVES USING BEST DESIGN FOR BUDGET

(1985 PRICES)



Methodology

The risks associated with a large sediment movement are demonstrated by comparing the effects of a 100 year frequency storm event, in addition to average annual hydrologic events, on the NED plan and the dredging option. Rare frequency events in the Toutle basin are usually caused by large accumulations of snow, followed by rapid increases in temperature and heavy rainfall which results in large flood flows.

Evaluation

The increase in average annual damages caused by an additional 100 year event would be negligible with respect to the NED plan. Average annual damages remain at $1.84 million for the NED plan.

The dredging option, however, constitutes a reactive plan, since it removes sediment that has settled in the Cowlitz and Toutle Rivers. Consequently, this alternative incurs greater risks associated with an additional 100 year frequency flood event. Under the dredging option, the additional 100 year event will deliver an increase of 13.5 mcy of sediment to the Cowlitz River, of which 5.1 mcy would be deposited in the river and require dredging. Removal of this sediment would require approximately 20 weeks; during this time levels of protection would be reduced for communities along the Cowlitz River. Table C-25 displays levels of protection which would exist under the dredging option, immediately following an additional 100 year event.

Table C-25
LEVELS OF PROTECTION
DREDGING OPTION WITH 100 YEAR FREQUENCY FLOOD
(recurrence interval in years)

Location	Toutle 1987-1998	Cowlitz 1999-2035
Longview	71	61
Kelso	56	51
Lexington	111	91
Castle Rock	33	8

Timing of an additional 100 year event is critical to the assessment of risk. For example, if the event occurred during late fall to spring, the Cowlitz River could not be dredged in time to restore channel conditions for the remaining flood season, substantially increasing the flood risk. Flood water elevations would remain higher and protection levels would remain lower than the average annual condition. During this time, average annual damages would increase from $4.2 million (dredging option) to $7.3 million. Average annual damages remain at $1.8 million for the NED plan.

The cost impact of the additional 100 year event is related directly to available storage remaining behind the SRS. Costs to dredge the additional sediment would be deferred to the out-years, and possibly beyond the 50-year life of the project. The base condition would incur increased average annual damages of $3.1 million, as well as the cleanup costs of increased sediment in the river at the point in time of the occurrence. Average annual costs cannot be determined for either alternative because they are dependent on the year in which the flood event occurs. Therefore, these costs were not estimated.

Conclusion

The dredging option is more sensitive to additional low frequency flood events than the NED plan. If an additional low frequency flood occurs, levels of protection will remain the same under the SRS option, but will decrease significantly for the dredging alternative until a base level of protection can be restored.

APPENDIX D

U.S. FISH AND WILDLIFE SERVICE
CONTINUING PLANNING AID
LETTER

FISH AND WILDLIFE COORDINATION

Coordination with the resource agencies has continued during the CP&E investigations and during the preparation of this Decision Document. Included as an appendix to this document is a Continued Planning Aid letter from U.S. Fish and Wildlife Service (FWS) which addresses the SRS alternative and, to a limited extent, the dredging alternative. Included in this report are mitigation and monitoring costs proposed by U.S. Fish and Wildlife Service. A review of the relationship of this report to earlier recommendations by FWS and Corps responses to those recommendations is warranted. A second letter from FWS dated 30 September 1985, discusses the SRS and dredging alternatives further.

FWS has been involved during all planning stages involving Mt. St. Helens recovery efforts, pursuant to the Fish and Wildlife Coordination Act. This involvement led to FWS preparing a Coordination Act Report (CAR) as part of the Feasibility Report. The CAR addressed, in detail, the SRS alternative and proposed specific mitigation and monitoring recommendations for that alternative. The Corps responded, point by point, to the recommendations of FWS in the Feasibility Report. The Feasibility Report, and specifically the point by point responses in that report, should be referenced concerning the Corps position on the current recommendations of FWS regarding the SRS alternative. The dredging alternative has not been examined in detail by FWS and will require a supplement to the CAR if this alternative is pursued.

The following general mitigation and monitoring requirements were delineated in the Feasibility Report. The primary mitigation associated with the SRS alternative is the provision of fish passage facilities at the structure. Separable costs associated with this passage include initial construction costs which will be a Federal responsibility and operation and maintenance costs which will be provided by the State of Washington as part of their cost-sharing responsibility. The SRS alternative was not to acquire any lands or easements for specific fish and wildlife mitigation purposes. It was proposed, however, to manage lands acquired for the reservoir to provide wildlife habitat primarily by protecting and preserving existing habitat and to provide some limited revegetation. Revegetation of disposal sites

associated with downstream measures would be seeded and fertilized at Federal expense with any additional revegetation borne by the local sponsor.

FWS also recommended in their CAR, which was expanded in their CPAL, that certain riparian and instream habitat improvements be provided with the SRS alternative. Incremental analysis of these FWS recommendations are currently underway to determine benefits, costs, and institutional arrangements for potential implementation. The direction to be taken in these evaluations was discussed in the Feasibility Report.

FWS had also recommended in their CAR, which was expanded in the CPAL, that detailed monitoring studies be implemented as part of the SRS alternative. The response to these earlier monitoring recommendations was, "We believe that the evaluations and studies you have recommended are too general and all-encompassing. Many of the studies you have recommended are not directly related to this project, but rather are studies more oriented toward determining impacts of the eruption and the recovery of fish and wildlife from that devastation. While we believe that certain studies relating to water quality, streamflow, and success of fish passage measures are warranted, we believe that the other studies you have recommended should more appropriately be a responsibility of the local fish and wildlife agencies as part of their normal monitoring process. We will coordinate with you the extent of studies and appropriate agency to provide those investigations relating to water quality, streamflow, and the success of fish passage facilities." The monitoring program and proposed interagency agreement recommended by FWS in the CPAL are not consistent with this earlier Corps response and will not be pursued.

The principle purpose of the CPAL was to obtain preliminary mitigation costs information on the dredging alternative for cost comparison purposes. Mitigation costs proposed include land acquisition and development to compensate the loss of fish and wildlife habitat through dredged material disposal. If the dredging alternative is pursued, a supplement to the CAR will be required which will examine specific mitigation and monitoring costs associated with this alternative.

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Division of Ecological Services
Portland Field Office
727 N. E. 24th Avenue
Portland, Oregon 97232

Reference KL:mm

August 2, 1985

Colonel Robert L. Friedenwald, District Engineer
Portland District, Corps of Engineers
P. O. Box 2946
Portland, Oregon 97208

Dear Colonel Friedenwald:

The attached report is the Service's Continued Planning Aid Letter (CPAL) on the proposed single retention structure (SRS) on the North Fork Toutle River. The CPAL evaluates the proposed fish passage design at the SRS, provides additional information on the costs and benefits of specific instream habitat improvements, includes a proposed monitoring program, and discusses the dredging option as an alternative to the SRS.

Sincerely,

Russ Peterson

Russell D. Peterson
Field Supervisor

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Division of Ecological Services
Portland Field Office
727 N. E. 24th Avenue
Portland, Oregon 97232

Reference KL:mm

August 2, 1985

Colonel Robert L. Friedenwald, District Engineer
Portland District, Corps of Engineers
P. O. Box 2946
Portland, Oregon 97208

Dear Colonel Friedenwald:

This is the Service's Continued Planning Aid Letter (CPAL) regarding the proposed single retention structure (SRS) at the Green River site on the North Fork Toutle River. The Service prepared a Coordination Act Report (CAR) on the impacts related to construction of the SRS in December, 1984. In that report, several mitigation features were discussed, including fish passage at the dam, instream habitat improvement measures, and riparian plantings designed to offset some of the losses to fish and wildlife incurred by the dam. Development of a monitoring plan was also recommended. The following material will provide additional analysis on costs and benefits of several features relating to mitigation for the proposed dam.

The Corps of Engineers (CE) is also examining other alternatives to the SRS in more detail. The Service's preliminary comments on two dredging alternatives are included in this report.

Fish Passage Design

The fish passage facilities for the proposed Green River Dam would consist of a series of outlet works in the face of the dam for juvenile fish passage and a fish barrier, ladder, and trap to collect adult fish for transportation upstream of the project. The following comments developed through coordination with the National Marine Fisheries Service (NMFS) and Washington Department of Fisheries (WDF) are preliminary in nature, but are intended to provide information on the possible problems that may occur with this design and suggested corrective changes.

1. The slope (5%) from the velocity barrier to the existing grade is probably too steep to pass adult fish. It may be possible to increase the drop at the barrier to about 20 feet and reduce the slope to a permissable 3.3%.

2. At least three entrances would be needed in the collection facility entrance pool due to the range of energy to be dissipated. Fishway flows should be designed for 100 cfs at the entrance.

3. A stilling basin below the velocity barrier would need to be large enough to permit collection of adult fish at flows of up to 5,000 cfs.

4. Flow distribution over the fish barrier must be evenly distributed to prevent false attraction of adult fish.

5. Approach velocities in the velocity barrier forebay should be minimized.

6. Velocity in the exit channel may be too high to allow for upstream passage by adult fish.

7. The adult low flow channel may need sills to improve passage.

8. It would be advantageous to design the dam with an ogee spillway rather than a v-notch. The ogee design helps prevent fish from separating from the water column (spill nappe), particularly at low flows, thus reducing juvenile fish mortalities.

9. As the juvenile passage outlets close off with debris, there will be decreased clearances for fish passage. Due to increased velocity at these sites, fish may become entrained against the debris. Some method of cleaning debris from the outlets should be designed.

10. An access point for the distribution of adult fish into the North Fork Toutle River upstream of the dam must be provided, preferably at the upper end of the sediment pool.

11. Operation of the trap and haul facility will be necessary periodically throughout the year.

Instream Habitat Improvement Measures

Several types of habitat improvement measures are available for use in the streams that were recommended for improvement in the December CAR. Root wad placement, culvert repair, and debris removal and/or placement are some of the more common methods that have been used by the WDF to improve fish habitat on the Green and South Fork Toutle Rivers. These methods are recommended for the streams listed in Table 1. Initial costs and annual benefits for the mitigation work in each of these streams are also presented in this table. The methodology and calculations used to determine benefits are presented in Appendix I. Costs of each improvement measure are summarized in Appendix II. Yearly benefits accruing to the

Table 1. Costs and benefits associated with instream habitat improvement measures for the Green and South Fork Toutle River tributaries.

Stream	Fish Increase	Improvement Measure	Cost	Benefit	O&M
Goat Creek	325 (SPCH)	DR/DP/RV1/	$22,000	$44,400	$2,000
Dollar Creek	46 (CO)	DR/poss.CR	3,200	1,700	300
Thirteen Creek	600 (CO)	BL/DR	20,000	23,000	2,000
	47 (ST)	BL/DR		7,500	
Disappointment Creek	19 (CO)	DR/RV	5,500	700	600
Herrington Creek	137 (CO)	DP	22,000	5,200	2,200
	11 (ST)			1,700	
Tributary opposite Trouble Creek	34 (CO)	DP	16,500	1,300	1,600
Unnamed Creek	183 (CO)	BL	30,000	7,000	3,000
(S. Fork)	14 (ST)	BL		2,200	
Johnson Creek	30 (CO)	DP	1,000	1,200	100
Wyant Creek	274 (CO)	CR	25,000	10,600	2,500
	21 (ST)	CR		3,400	
Outlet Creek	1,520 (CO)	CR	25,000	58,900	2,500
Miners Creek	255 (SPCH)	DR/RV/BL	35,000	35,000	4,000
	24 (ST)	DR/RV/BL		3,900	
Unnamed tributary near Tower Road	15 (CO)	DP	3,000	600	300
Shultz Creek	45 (CO)	RV	500	1,700	
Elk Creek	365 (CO)	DP/BL	47,000	14,100	5,000
Devils Creek	1,216 (CO)	BL/DP	23,000	47,100	2,300
	94 (ST)	BL/DP		15,000	
Side Channel Development (S.Fork Toutle)	600 (CO)	RC,DP	95,000	24,000	6,000

1/ Revegetation is limited to Department of Natural Resources (DNR) lands - some revegetation has already occurred on Weyerhaeuser land.

Legend: SPCH - spring chinook
CO - coho
ST - steelhead
DR - debris removal
DP - debris placement
RV - revegetation
CR - culvert removal/repair
BL - blasting and laddering of a falls
RC - riprap and culvert placement at upstream end of excavated channel

---

stream fisheries as a result of habitat improvement amount to approximately $310,000 (by year 2020). Initial costs are estimated at $374,000. Operation and maintenance (O&M) costs will vary with the improvement measure. Riprapping and excavation are considered one-time costs with no O&M. Other measures such as blasting, laddering, rootwad placement, culvert repair and/or installation, and debris removal will require O&M expenditures. These costs are detailed in Table 1.

An estimate of the benefits of these same measures on resident cutthroat trout production approaches $25,000.

Riparian Plantings

Improvement of stream habitat and riparian areas outside the sediment inundation zone will be used to offset riparian habitat losses caused by the SRS and/or disposal at dredge spoil sites. Instream temperature control, sediment and erosion control, and wildlife habitat mitigation can be achieved to some degree by establishment and maintenance of streamside vegetation. Streams which would be suitable for revegetation include: Goat, Disappointment, and Trouble Creeks on the South Fork Toutle River; Miners and Shultz Creeks on the Green River; and a number of short, unnamed tributaries to the North and South Forks of the Toutle River and along the Green River.

Species appropriate for planting in these areas include red alder, Sitka willow, western red cedar, grand fir, and western white pine. Associated herbaceous species should include New Zealand white clover, and Marshfield big and birdsfoot trefoils. Some areas could be planted to sickle-keeled lupine, although it is not suitable for planting with trees. This species is a nitrogen producer and can produce as much as fifteen tons green weight/acre in two years. Because of its size and weight, it may also aid in rill erosion control. All of these tree and herbaceous species have been used in revegetation trials in the project area and grew successfully. Planted areas will also need to be fertilized at the time of planting (300 lbs/acre of 10-20-20). The optimum planting time is March and April. The riparian corridor width would be subject to negotiation. A lead time of one to two years is needed for ordering trees.

Most of the areas that would benefit from planting are private holdings, with the Weyerhaeuser Company being the principal landowner. Some of the streams identified above have already been planted as a result of Weyerhaeuser initiative. However, the streams would benefit from additional planting. An increase in the diversity of the plantings would also increase their wildlife value. There is also a possibility that DNR lands could be planted with riparian species. However, most of the DNR lands associated with the identified streams are higher in the headwaters and would not provide the same advantage as those lands near the stream mouths. Land availability and selection of specific sites for mitigation measures would be negotiated with the affected public and private landowners. Negotiations would attempt to maximize the benefits of the various mitigation measures while minimizing any interference with ongoing land management plans and actions. Data on general material costs and labor associated with riparian revegetation are contained in Table 2.

Monitoring Plan

A monitoring plan was recommended in the Service's December, 1984 report to help assess the impacts of the dam as well as to determine the success of the various mitigation measures covered in the report. A draft plan is attached which identifies several tasks which are designed to evaluate the effectiveness of instream habitat improvement measures, effects of water quality released from the dam on downstream fish recovery, success of upstream and downstream fish passage, and the overall impacts of the dam on fish and wildlife recovery in the Cowlitz-Toutle drainage.

The Dredging Alternative

The CE has requested the Service to provide preliminary comments on two dredging alternatives; dredging to maintain base protection, and dredging to increase flood protection with base channel geometry.

The base condition, as adopted by the CE, is the level of protection afforded by channel geometry in November-December 1983. At this base, Longview is protected against a 60-year flood event, Kelso and Lexington a 20-year event, and Castle Rock a 10-year event. The dredging alternatives would probably be combined with raising of levees.

In earlier Fish and Wildlife Coordination Act Reports, only the SRS alternative was examined in detail. Other alternatives were given a cursory appraisal, based on limited information. During the earlier analyses, it was recognized that all the alternatives had some negative fish and wildlife effects. The resource agencies indicated a preference for removing sediment in the Toutle River Basin through dredging or the SRS. The primary concern with the dredging alternative was that remaining important habitat in the lower Cowlitz and the Columbia Rivers would be lost through dredge disposal. Shoaling of shallow water habitat in the

Table 2. A general estimate of material and labor costs associated with a riparian revegetation program

<u>Trees</u>

Species: Red alder, Sitka willow (no material cost), western red cedar, grand fir, western white pine

Cost: $125-$300/1,000 trees (depending on species)

Spacing: 10' X 10'

<u>Herbaceous plants</u>

Species: New Zealand white clover, sickle-keeled lupine, Marshfield big trefoil, birdsfoot trefoil

Cost: New Zealand white clover: $1.00/lb.
Sickle-keeled lupine: $5-7/lb.
Marshfield big trefoil: $3.25/lb.
Birdsfoot trefoil: $2.50/lb.

Seeding rate: 10 lbs/acre

<u>Fertilizer</u>

Type: 10-20-10

Cost: $205/ton

Application Rate: 300 lbs/acre

<u>Labor</u>

Planting: $300-500/man day

Washington Conservation Corps (Washington Parks): $3.50/hour

Private contractor: $6.50/hour

Columbia River and the estuary by bedload and suspended sediments was also a concern. Based on early sediment analysis, it appeared that the dredging alternative would require extensive dredge disposal along the Columbia River and the mouth of the Cowlitz River. Because of the severe habitat loss, the SRS alternative was preferred.

The CE has requested a more detailed analysis of the environmental impacts and mitigation costs of the dredging alternative as part of their present investigations leading to preparation of the Decision Document. A number

of disposal sites along the lower Cowlitz River (River Miles 0 to 23), as well as LT-1, LT-3, and NF-1, have been identified by the CE. The acreage of the sites and the habitat types on the sites have been identified through use of a Geographic Information System (GIS). However, at this time, information on the amounts of material to be dredged, the location of the dredging, or sites to be used is not available.

There are several other aspects of the dredging alternative which would also have to be addressed. They include: raising of levees; areas to be allowed to flood; the life of disposal sites at LT-1, LT-3, and NF-1 and alternate disposal sites; and any other measures. Until details on the above items, as well as on dredge amounts and location, are available, we are not able to adequately compare the effects of the dredging alternative with the SRS alternative.

A preliminary estimate of mitigation requirements and costs was developed based on habitat types. Habitats were grouped into three categories and a mitigation formula was developed to arrive at approximate mitigation costs for each category. These costs are approximate and will need to be developed in greater detail if this alternative is pursued further.

Mitigation Categories

Category 1

Habitat Types: Disturbed Revegetated (DR), Dredge Material Disposal (D), Urban Residential (UR), Urban Industrial (UD), and Other (O).

Category 1 sites should be used first for dredged material disposal. No additional land acquisition is necessary to replace habitat values lost on these sites. Values can be mitigated on-site by shaping and contouring the material and by seeding and fertilizing the site after disposal.

Category 2

Habitat Types: Grasslands (G); Shrublands (S); and Agriculture (A).

Category 2 sites should be used after Category 1 sites are filled. It is estimated that replacement of habitat values on an acre for acre basis would be required. Replacement would not have to be in-kind. On-site habitat improvement like those required in Category 1 would be required.

Category 3

Habitat Types: Forested Wetland (FW); Shrub-Scrub Wetland (SS); Emergent Wetland (E); Forest (F); and Open Water (O).

Category 3 sites should be avoided if possible, particularly forested wetlands. It is estimated that in-kind habitat replacement of 1.5 acres for each acre lost would be required. On-site habitat improvements to the disposal site would also be required.

Mitigation Costs

Costs of land acquisition are predicated on use of diked pasture (former freshwater wetlands) in the area from the mouth of the Cowlitz River downstream to the lower end of Puget Island. Based on previous Corps projects, shaping and revegetation of disposal sites was estimated to be $3,000 per acre. Improvement of Category 3 mitigation sites to create wetlands would cost approximately $4,500 per acre. Category 2 mitigation sites should require less manipulation and costs were estimated to be about $3,000 per acre.

Establishment of vegetation on both disposal and mitigation sites would require more intensive management the first three years to ensure success of the revegetation efforts. These costs were estimated at $1,000 per acre per year. Long-term (life of the project) maintenance costs for Category 3 mitigation sites were estimated to be $100 annually. Category 2 sites would require maintenance every 2 to 3 years. Costs were estimated at $35 to $50 annually. Category 1 sites would not require annual maintenance. Table 3 summarizes the mitigation requirements and costs.

Table 3. Preliminary mitigation requirements and costs for the dredging alternative.

Mitigation	Site Categories		
	1	2	3
Requirements			
On-site	Yes	Yes	Yes
In-kind	No	Yes/No	Yes
Land acquisition	No	Yes	Yes
Amount (Acres)	0	1 to 1	1 to 1.5
Costs per acre 1/			
Land acquisition	-0-	$3,000-3,500	$3,000-3,500
Development			
Disposal site	$3,000	$3,000	$3,000
Mitigation site	-0-	$3,000	$4,500
Operation & Maintenance			
Establish vegetation (3 yrs.)	$3,000	$3,000	$3,000
Long-term maintenance (annual)	-0-	$35-50	$ 100

1/ Cost figures supplied by Corps of Engineers.

DISCUSSION

There are several features of the proposed SRS that will need to be analyzed further. The fish passage design should be adequate provided the concerns regarding the spillway, ladder entrances, channel slope, and attraction flows are addressed. However, these adjustments, changes, etc. will have to be monitored along with the fish passage as a whole to determine how quickly fish recover.

A monitoring study will be necessary to determine not only the effectiveness of the SRS for improving downstream conditions for fish and wildlife, but to determine how well the mitigation measures accomplish their intended purposes. The draft monitoring plan submitted with this report is intended to be an interagency agreement which will be coordinated with and carried out by the Corps, state, and federal resource agencies. The cost of such a plan will vary depending on what tasks are jointly identified as being necessary to accomplish the study. The WDF has also submitted a draft monitoring study proposal which relates directly to adult and juvenile fish recovery in the affected Cowlitz-Toutle River drainages. This draft proposal is actually a more concrete description of Tasks 2, 3, and 4 contained in the Service's proposed study. The final monitoring plan should be a composite of these approaches.

Riparian plantings for fish and wildlife mitigation would only be marginally successful if limited to public lands. The majority of the land suitable for planting is privately owned, and therefore may not be available for mitigation work. Available public land is located further up in the headwaters of the designated streams. While plantings in headwater areas may be beneficial to fish and wildlife on a local basis, they would not maximize beneficial water temperature (shading) effects or food and cover benefits near the mouth(s) of the streams. Nevertheless, we believe that revegetation of selected upstream areas, in combination with that planting which has already been done on private land, would provide some worthwhile benefits to fish and wildlife.

As project planning continues, additional consideration should be given to stream habitat improvement and revegetation of selected areas upstream of the SRS. This would be especially important if private lands could not be made available for riparian plantings. An overall plan for stream habitat improvement and riparian plantings should be developed through a coordinated effort involving the CE, resource agencies, and participating landowners. Such a plan could be flexible, allowing for the identification of specific sites for stream habitat improvement measures and riparian plantings during project construction and through the monitoring process.

With regard to the proposed dredging option, it is not possible to determine whether or not the dredging alternative is preferable to the SRS. In general, if dredging is confined to the upper watershed (Toutle

and upper Cowlitz Rivers) and timed to minimize fish and wildlife impacts, the dredging alternative might be preferable to the SRS. However, if dredging includes the filling of productive fish and wildlife habitats, then the SRS alternative would be preferable. If the dredging alternative, or any alternative other than the SRS is pursued, a supplemental Fish and Wildlife Coordination Act Report would be required.

Sincerely,

Russell D. Peterson

Russell D. Peterson
Field Supervisor

DRAFT

INTERAGENCY AGREEMENT
BETWEEN
THE U.S. FISH AND WILDLIFE SERVICE
AND
THE U.S. ARMY CORPS OF ENGINEERS, PORTLAND DISTRICT

This agreement is entered into by the Fish and Wildlife Service (Service) and the U.S. Army Corps of Engineers (CE) as a means of more accurately determining the quantity and quality of fish and wildlife mitigation required as a result of impacts produced by the proposed single retention structure (SRS) on the North Fork Toutle River and for monitoring the success of the project in achieving fish and wildlife mitigation goals.

Article 1 - Background

The Mt. St. Helens eruption occurred on May 18, 1980 and destroyed fish and wildlife and their habitats throughout a 20 mile radius north of the mountain. In addition, it produced a debris flow that filled the upper 15 miles of the Toutle River flood plain with eruptive material to a maximum depth of 200 feet. A pyroclastic flow inundated the remaining 15-20 miles of the Toutle flood plain as well as all 25 miles of the South Fork Toutle and over 10 miles of the Cowlitz River. Further, the upper portion of the watershed was blanketed with ash and tephra ranging from one to four inches in depth.

Almost immediately, pioneer plants began reestablishing. Today, deer and elk are returning in unexpectedly large numbers and salmon are spawning in some of the tributaries after negotiating the turbid main stem of the Toutle River. Deer, elk, and bear populations have recovered sufficiently so that hunting is once again permitted in the area. Pre- eruption salmon spawners for the Toutle drainage numbered 15-20,000. Today, the State fish and game agencies estimate that salmon and steelhead have returned in small numbers to all but the most severely affected streams in the Toutle Basin.

A discharge tunnel to control Spirit Lake levels has been completed. Spirit Lake discharges are now routed into the North Fork Toutle River via South Coldwater Creek and Coldwater Lake. Approximately five miles of the North Fork Toutle River have been bypassed by the tunnel.

The CE has carefully examined a number of methods for controlling the downstream movement of sediment and the attendant risk of flooding. Serious attention is being given to the following project alternatives: (1) a single sediment control structure on the North Fork of the Toutle just above the mouth of the Green River in combination with some additional dredging on the mainstem Toutle, Cowlitz, and Columbia Rivers; or (2)

continued maintenance dredging of the Toutle, Cowlitz, and Columbia at critical points to reduce the risk of flooding and maintain ship channel depths.

The principal impact of a sediment control structure would be interference with upstream and downstream passage of salmon and steelhead to and from spawning and rearing habitat in the North Fork Toutle River as well as its tributary streams. The dam would also curtail gravel recruitment in stream areas below the structure. On the other hand, it would reduce the length of time sedimentation would continue to pose a problem. Wildlife habitat, including some riparian habitat, would be eliminated in the sediment pool behind the dam and in downstream areas as a result of spoil disposal. However, under this option, wildlife losses would be comparatively limited since much of the sediment would be retained within the Toutle Basin and in areas already heavily impacted by the eruption.

Use of dredging alone would eliminate impacts on steelhead and salmon passage. However, downstream erosion and sedimentation would continue for a longer period of time. Impacts on terrestrial and wetland habitats in downstream areas, especially the Cowlitz River, would be greater under this option because the acreage needed to accommodate spoil would be significantly larger and in areas not affected to a great degree by the eruption.

Under either option, releases from the new outlet at Spirit Lake must be carefully monitored to assess possible changes in water quality, expecially those of temperature and flow. Their impact on the anadromous resource and measures for correcting water quality deficiencies would also require evaluation.

Article 2 - Study Scope and Goals

Impacts attributable to CE work have been estimated and recommendations for mitigating these losses have been furnished. However, specific data on the rate and degree of recovery of fish and wildlife due to CE works (SRS, dredging, etc.), as well as the effectiveness of the proposed mitigation in resolving project-related problems is presently unavailable. Therefore, detailed studies must be initiated to document the level of mitigation needed and to determine if it is satisfactorily accomplishing its intended purpose.

To initiate work on such an effort, the FWS and the CE agree that: (1) the tasks listed in Article 3 of this agreement are to be implemented in good faith by both parties to insure that adequate mitigation of fish, wildlife, and habitat losses attributable to the SRS is provided; (2) both agencies will work cooperatively with other entities concurrently engaged in the restoration of the basin's fish and wildlife resources; and (3) the duration and content of the tasks will be modified or terminated by mutual

consent of both parties when changing conditions in the study area or other factors dictate such action.

Article 3 - Fish and Wildlife Tasks

The tasks listed below are to be implemented by or through an agency designated by the FWS to determine the quality and quantity of mitigation features needed as well as to assess mitigation performance. The FWS will furnish the CE with recommendations for modifying any mitigation programs or project facilities based on study findings. Attached to this agreement are examples of two study plans, one developed for Task 5 below and one developed by the Washington Department of Fisheries (WDF). These plans are preliminary in nature. Eventually, however, a plan for each task will be developed which will guide the actual conduct of the study, as well as describe what actually will be done, how long it will take, and how much it will cost. These documents will be subject to change by mutual consent as conditions dictate without modifying the basic agreement.

The tasks to be performed are outlined below.

FISHERY TASKS

Task 1. CE and Washington Department of Social and Health Services (DSHS) continue to sample water quality conditions for toxic materials and monitor turbidity, sedimentation and erosion, temperature, dissolved oxygen, and changes in stream morphology in the North Fork Toutle, Toutle, and Cowlitz Rivers.

Objectives

1. Eliminate health risks to field workers.

2. Obtain data reflecting the rate of stream recovery and identify potential problem areas.

Task 2. To better determine how the SRS is affecting fish recovery, collect baseline data on adult anadromous fish populations on a continuing basis via a variety of survey methods (weirs, nets, electrofishing, etc.) at the mouth of the Toutle, North Fork Toutle, South Fork Toutle, and Green Rivers as well as at the SRS site.

Objectives

1. Determine trends in escapement.

2. Correlate adult fish population trends to changes in habitat quality and quantity assessed under Tasks 5 and 6 for with and without conditions in order to document needed habitat improvements.

3. Furnish population data for determining when fish passage facilities should be operative.

4. Determine the impact of the sediment control structure on the upstream migration of salmon and steelhead in the Toutle River during pre- and post- construction as well as with the trap and haul facility in place.

5. Establish a fish population basis for determining the impacts of project construction on adults for use in justifying or rejecting pre-project fishery mitigation proposals.

<u>Task 3</u>. Collect juvenile fish population data for salmon/steelhead at selected control points on the North Fork Toutle River above and below the SRS under with and without project conditions and with the passage facilities in place. These surveys will provide baseline data useful in determining the impacts of the SRS.

<u>Objectives</u>:

1. Review existing data. (The Washington Department of Game, (WDG), has already surveyed many of the streams in question).

2. Determine trends in survival.

3. Correlate juvenile fish population trends to changes in habitat quality and quantity under Tasks 5 and 6 for with and without project conditions in order to document needed habitat improvements.

4. Determine how effectively fish passage facilities operate and furnish recommendations for modifying operations or structures.

5. Assess the condition of juveniles before and after use of the downstream passage facility in order to document any required modifications in structure or operation.

6. Monitor survival of fry and determine the causitive factors of juvenile mortality.

<u>Task 4</u>. Collect juvenile fish population data for salmon/steelhead at selected control points on the South Fork Toutle and Green Rivers under with and without project conditions and with passage facilities in place.

<u>Objectives</u>:

1. Review existing data.

2. Determine trends in survival.

3. Correlate juvenile fish population trends to changes in habitat quality and quantity assessed under Tasks 5 and 6 for with and without project conditions in order to document needed habitat improvements.

Task 5. Exclusive of areas above the proposed dam, establish fixed control points or transects on the main stem Toutle and tributaries below the Green River site and monitor changes in the quality and quantity of critical habitat factors for adult and juvenile steelhead/salmon under with and without project conditions.

Objectives:

1. Review existing data.

2. Correlate population data obtained under Tasks 2, 3, and 4 with instream habitat data in order to determine and monitor the critical habitat factors that promote anadromous fish restoration and replenish these factors in order to increase the numbers of salmon and steelhead.

3. Assess and monitor what, if any, impact the sediment control structure has on sedimentation and gravel recruitment in downstream areas in order to quantify mitigation needs.

4. Determine what impact flows from Spirit Lake through South Coldwater Creek and Coldwater Lake have on stream quality with specific emphasis on temperature and discharge levels.

5. Determine what, if any, additional facilities or structures are required to mitigate construction of the sediment control dam. (Some mitigation measures have already been determined, i.e., certain instream habitat improvements, fish passage at the dam, etc.).

Task 6. Establish fixed control points or transects in areas above the Green River site and monitor changes in the quality and quantity of critical habitat factors for adult and juvenile steelhead/salmon under with and without project conditions.

Objectives:

1. Review existing data.

2. Correlate population data obtained under Tasks 2, 3, and 4 with instream habitat data in order to determine and monitor the critical habitat factors that promote anadromous fish restoration and replenish these factors to increase the numbers of steelhead and salmon.

3. Assess and monitor the quality and quantity of habitat in areas above the control structure to determine when passage facilities should be operative and assess the need for habitat improvement to accommodate the level of returning adults.

4. Provide a control plot for comparing the impact the sediment control structure is having on downstream gravel recruitment.

5. Determine what impact flows from Spirit Lake through South Coldwater Creek and Coldwater Lake have on stream quality with specific emphasis on temperature and discharge levels and assess the level of control furnished at the new Spirit Lake outlet works.

Task 7. Collect juvenile health data for salmon/steelhead at selected control points on the North Fork of the Toutle under with and without conditions and with passage facilities in place.

Objectives:

1. Determine fish health under with and without conditions above and below the dam.

2. Document any factors other than physical habitat conditions that may be limiting restoration.

3. Assess the success of passage facilities and recommend appropriate modifications.

Task 8. Continue to conduct spawning ground surveys at established locations throughout the basin. WDG and WDF should correlate these data.

Objectives:

1. Assess the quantity of spawning below the dam under with and without conditions.

2. Assess the quántity of spawning above the dam with passage facilities in place.

3. Determine where the predominate amount of spawning is taking place in the basin.

4. Guide rehabilitation efforts in both productive and unproductive areas based on data obtained under Tasks 5 and 6.

5. Assess the success of passage facilities.

Task 9. Based on study findings recommend development and installation of features for mitigating and enhancing the anadromous resources of the Toutle River watershed.

Objectives:

1. Act on study findings by installing features necessary for mitigating impacts to the anadromous resource.

2. To provide a source of funding for the required work and facilities.

WILDLIFE TASKS

Task 1. Using reconnaissance level aerial photography, determine the general quantity and quality of wildlife habitat in the eruption-affected areas of the Toutle-Cowlitz Basin, exclusive of the volcanic monument. Establish wildlife census route(s). After reconnaissance, select an area(s) comparable in size and habitat behind the proposed SRS and on the dredge spoil sites. This will provide a comparison/gauge of project impacts and mitigation efforts.

Objective:

Furnish baseline conditions for monitoring project impacts on wildlife habitat.

Task 2. Using aerial photography, in combination with field surveys, prioritize wildlife habitat yet to be impacted by project dredging or disposal along the Toutle River and near the Cowlitz sump.

Objective:

Protect as much vital wetland, riparian, and big game critical habitat as possible.

Task 3. (a) On a periodic basis, in combination with field checks, determine the quantity and quality of wildlife habitat losses resulting from CE actions throughout the affected area and determine the success of the mitigation program. Periodic post-project evaluations of habitat condition using the Habitat Evaluation Procedures (HEP) would be useful in this regard. (b) Follow census route(s), both in CE project area and in comparison area, to monitor wildlife use. Species of interest include elk, deer, bear, cougar, furbearers, and nongame species (songbirds, reptiles, and amphibians). For big game species, some attention should be directed to migration routes and reproductive areas.

Task 4. Modify mitigation requirements as needed, based upon results of above tasks.

Objective:

Adjust wildlife mitigation so that the most effective use of funding resources is made.

Article 4 - Service Responsibilities

The Service is charged with the ultimate responsibility for the design and conduct of all biologically-related tasks following good faith coordination with CE and State fish and game personnel.

The Service is responsible for the successful completion of all tasks in accordance with the requirements of each approved study plan.

The Service may contract with the State fish and game or other entities to accomplish all of a task or a portion thereof.

Article 5 - Corps of Engineers Responsibilities

The CE will make available to the Service hydrological and engineering data collected in the affected watershed as a part of the project and will, in good faith, consider recommendations concerning the collection of additional data of this type when it could assist in the development or analysis of fish or wildlife tasks.

Article 6 - Fiscal Responsibility

The CE will fund the Service to implement the tasks listed in this agreement. Such funding will correspond as closely as appropriations will allow to the funding needs displayed in the mutually approved study plans accompanying each task. Every effort will be made to accommodate Service specified needs associated with the project although study plans must be mutually approved and endorsed by the State fish and and game agencies.

Funds will be made available under a reimbursable agreement employing the process now employed between the Service and the CE in funding Service work under the Fish and Wildlife Coordination Act at federal projects.

The Service may sub-contract with a mutually approved entity to accomplish part or all of a task and is authorized to assess a 15 percent overhead charge for its involvement in such an effort. First right of refusal will be afforded the State fish and game departments.

Article 7 - Obligational Authority

If there is no approved appropriation bill prior to the start of the fiscal year, obligational authority for ongoing studies will be furnished to the FWS and others under contract provided Congress furnishes the CE with such authority.

Article 8 - Annual Review

Annually, the Service will thoroughly review the progress being made on each study with the CE early enough in the fiscal year to permit changes in study plans or funding. The review will consist of both an oral presentation and a written summary report. The intent of this annual review is to reassess study findings to determine if each study is accomplishing its objectives or needs to be changed. The annual review should also be used to identify studies that need to be added or terminated, based on the results of ongoing efforts.

Article 9 - Arbitration

To the maximum extent possible, all conflicts are to be resolved at the lowest management level possible. Field and District personnel will negotiate in good faith to resolve issues. Only those problems that threaten the viability of the MOU are to be elevated to the District Engineer and the Regional Director for resolution.

Article 10 - Amendments

The MOU can be amended at any time by mutual consent of both parties.

Article 11 - Length of Study

The monitoring study will be implemented in 10 year increments. A review will be conducted at the end of each increment to determine if the study should be continued. This review will be in addition to that required under Article 12.

The MOU can be terminated by mutual consent of both parties at the end of a fiscal year following 30 day advance notice to sub-contractors.

A study plan or part thereof can be terminated at any time by mutual consent of both parties provided a 30 day advance notice is furnished to study personnel and sub-contractors.

Article 12 - Reports

At the end of every odd numbered year exclusive of 1, the Service will submit a report of study findings and conclusions to the CE with recommendations for any changes in the operation of the overall study. This will be in addition to the annual review and will serve as information for management to use in appraising the overall value of the work being conducted under the MOU. The format and content of such report will be mutually agreed upon following completion of the first year of study.

In addition, a final and detailed report will be prepared following completion or termination of a study. Such report will provide an executive summary and contain study findings and conclusions.

SAMPLE STUDY PLAN

Task No. 5. Exclusive of areas above the proposed dam, establish fixed control points or transects on the main stem Toutle and tributaries below the Green River site and monitor changes in the quality and quantity of critical habitat factors for adult and/or juvenile steelhead/salmon under with and without project conditions.

Objectives:

1. Review existing data.

2. Correlate population data obtained under Tasks 2, 3, and 4 with instream habitat data in order to determine and monitor the critical habitat factors that promote anadromous fish restoration and replenish these parameters in order to increase the numbers of salmon and steelhead.

3. Assess and monitor what, if any, impact the sediment control structure has on sedimentation and gravel recruitment in downstream areas in order to quantify mitigation needs.

4. Determine what impact flows from Spirit Lake through South Coldwater Creek and Coldwater Lake have on stream quality with specific emphasis on temperature and discharge levels.

5. Determine what, if any, facilities or structures are required to mitigate for downstream impacts from construction of the sediment control structure. (Some mitigation measures have already been determined, i.e., certain instream habitat improvements, fish passage at the dam, etc.).

6. Provide control points outside the area to be impacted by the dam in order to monitor differences in stream hydraulics under with and without conditions which will assist in identifying impacts attributable to the sediment control structure.

Total estimated fund and manpower requirements:

Job Completion Date:	1986-1998
Total Costs:	\$2,547,710 (\$212,309/yr)
Staffing Needs:	2 biologists for each year of study 2 biological technicians for initial 2 years 12 for remaining 10 years

Task 5, Job 1. Develop models for monitoring critical habitat factors.

Job Description: Select life stage of the species under study which are limiting.

Develop 3 mechanistic models each containing those variables for the above life stage(s) which are the principal factors controlling the population levels of steelhead and salmon. In completing this job, existing Service models will be modified to accommodate any particular regional habitat need. The models will be used to rank each selected variable on a scale of 0 to 1 based on field data collected for this purpose.

Test the modified models on six selected streams of known quality including tributaries of the Toutle River to determine if they mirror known conditions. Where appropriate, delete or add to the variables, modify the slope of the curve for each variable or otherwise change the model to optimize its responsiveness.

Finalize the models and furnish a descriptive summation of study findings plus an assessment of the capability of the model in identifying and monitoring critical habitat factors for the life stage(s) selected to the project officer and project leader. (Optional) If serious questions remain regarding the capability of the model to accomplish its stated purpose, conduct a year of testing on the Toutle River in both affected and non-affected stream areas to determine as best as possible, how well the model will perform based on available fishery data.

Estimated Time, Funds and Manpower Requirements:

Time: 2 year (first 2 years of study)

Funds and Manpower: 1 Biologist GS 11/12 for 8-month-Job Leader
$200.00/Bio Day @ 156 days/year = $31,200

1 Biologist GS 11/12 for 24 months
$200.00/Bio Day @ 420 days = $84,000

2 Biological Technicians for 2 years each
$100.00/Bio Day @ 210 days/year each = $84,000

Overhead cost (15 percent) = $29,880

Total Cost for Job 1 = $229,080

Total Cost for Job 1 if optional work included = $361,560

Task 5, Job 2. Develop a method for monitoring gravel recruitment and sedimentation below the proposed sediment control structure.

Job Description: From among the available standard sampling methods used to measure the quantity and quality of spawning gravel, select the one which would function best in the existing Toutle watershed and test it in the field.

Do the same for sedimentation.

Estimated Time, Funds and Manpower Required:

Time: 10 days

Funds and Manpower:	1 GS 11/12 Biologist for 10 days - Job Leader		
	$200.00/Bio Day @ 10 days	=	$2,000
	Overhead Cost	=	$ 300
	Total Estimated Cost of Job 2	=	$2,300

<u>Task 5, Job 3</u>. Review study plan findings periodically with the project officer and other interested parties.

Job Description: Review findings at this point with the project officer and any cooperators. Modify study plans if necessary to accommodate altered study conditions or findings.

Estimated Time, Funds, and Manpower Required:

Time: 5 days

Funds and Manpower Required:	1 GS 11/12 Biologist for 5 days		
	$200.00/Bio Day @ 5 days	=	$1,000
	Overhead Charge	=	$ 150
	Total Estimated Cost of Job 3	=	$1,150

<u>Task 5, Job 4</u>. Select transects at which to measure those parameters identified in Jobs 1 and 2.

Job Description: Survey the Toutle watershed using available mapping and aerial coverage in combination with field checks for the purpose of segmenting the main stem and selected tributaries below the SRS into representative reaches that contain similar hydrologic conditions.

Within each reach, identify habitat important to the life stage(s) to be evaluated with the models developed in Job 1.

Identify potential transects in each reach.

Select a balanced number of transects to be used in the study from among those identified above and mark their location in the field. Limit the number to an absolute minimum in order to minimize the expenditure of time and money while still maintaining a viable study.

Accomplish this in part at the time of the model testing period described in Job 1. Add remaining sites at the completion of Job 3.

Time, Funds and Manpower Required:

Time: 40 days

Funds and Manpower: 2 GS 11/12 Biologists for 20 days each

$200.00/Bio Day @ 40 days	=	$8,000
Overhead	=	$1,200
Total Job 4 Costs	=	$9,200

Task 5, Job 5. Collect Transect Data

Job Description: Collect data at the transects to monitor the habitat factors critical to the life stages of the anadromous fish under study.

Semi-annually review findings to determine what, if any, adjustments should be made in transect location and data collection parameters and methods for the first two years of the study and annually thereafter.

Time, Funds and Manpower Required:

Time: A 10-year initial effort ending in a report describing the success of the effort at minimizing the impacts on the anadromous resource from construction of the sediment control structure is considered minimal. There is no guarantee that further work will not be necessary. Additional increments will be mutually approved if watershed conditions or other unforeseen factors delay or otherwise impede the study.

Funds and Manpower:

1 GS 11/12 Biologist 105 Days/Year
$200.00/Bio Day @ 105 Days/10 Years = $210,000

1 GS 11/12 Biologist 210 Days/Year
$200.00/Bio Day @ 210 Days/10 Years = $420,000

12 Biological Technicians 105 Bio Days/Year
(3 teams of 4 people)
$100.00/Bio Day @ 105 Days/10 Years X 12 =$1,260,000

Sub Total	$1,890,000
Overhead (15 percent)	$ 283,500
Total Cost Job 5	$2,173,500

(Data analysis is included as part of the GS 11/12 Biologist supervising the job).

DRAFT MONITORING STUDY
FOR THE COWLITZ-TOUTLE BASIN
AS PROPOSED BY THE
WASHINGTON DEPARTMENT OF FISHERIES

Purpose: To monitor the foodfish resources and pertinent parameters in the area affected by the SRS proposed by the CE. This study is necessary to (1) collect and document baseline information relative to foodfish resource recovery rates occurring prior to construction of the SRS, (2) estimate mitigation needs, and (3) evaluate the accomplishments of any mitigation efforts.

Tasks

1. Consolidate and compile information relative to toxic materials, turbidity, sedimentation, temperature, dissolved oxygen and discharge. Collect specific information in selected index areas relative to physical stream bed rehabilitation and other critical habitat factors (large woody debris, etc.).

2. Collect juvenile fish population data in selected index areas. Salmon, steelhead and other fish species abundance will be documented.

3. Collect adult fish spawning information comprehensively in the study area. Adult salmon and smelt information will be collected comprehensively, and other species data collected whenever possible.

4. Collect catch information from any fisheries occurring in the study area.

5. Analyze juvenile fish population data in conjunction with habitat information for correlation to overall recovery patterns and limiting mortality factors.

6. Analyze adult fish catch and escapement information relative to recovery trends and any sediment control option impacts. Collected information will be integrated with existing data collection efforts in downstream areas to account for harvests and mortality factors unrelated to sediment control activity. The impacts of any rehabilitative or destructive efforts by parties other than the Corps of Engineers will be analyzed separately in a systematized parallel manner.

7. Provide a detailed publication documenting the results of tasks 1 through 6, on an annual schedule.

ESTIMATED ANNUAL BUDGET-WDF

PERSONNEL		
SALARIES		
Fish Biologist II	(1 FTE)	$24,200
Scientific Technician II	(1.5 FTE)	29,800
BENEFITS		
@ .23 of salaries		12,400
TRAVEL		4,000
EQUIPMENT		
(First year only)		2,500
SUPPLIES		3,000
OVERHEAD		
@ .26 of salaries		14,000
TOTAL		89,900

Appendix I. Basis for Calculations Used to Estimate Benefits of Instream Habitat Improvement Measures

Spring Chinook

Stream	Area (M^2)	Adults*	Benefit
Goat Creek	12,508	325	$44,400
Miners Creek	9,810	255	35,000

*Estimated at .26 smolts/M^2 and 10% smolt/adult survival.

Catch: Escapement	3:1	243:82 (Goat Creek)
43% Commercial		104 X $34.80 = $3,636
57% Sport		139 X $295 = 40,860
		$44,496

Coho

Stream	Area (M^2)	Adults*	Benefit
Dollar Creek	1,472	46	$1,700
Disappointment Creek	613	19	700
Herrington Creek	4,414	137	5,200
Stream	Area (M^2)	Adults*	Benefit
Tributary Opposite Trouble Creek	1,104	34	1,300
Unnamed Creek (S.Fork)	5,886	183	7,000
Johnson Creek	981	30	1,200
Wyant Creek	8,829	274	10,600
Outlet Creek	49,052	1,520	58,900
Unnamed Tributary near Tower Rd.	491	15	600
Shultz Creek	1,471	45	1,700
Elk Creek	11,773	365	14,100
Devils Creek	39,241	1,216	47,100
Thirteen Creek	19,620	600	23,000
Side Channel Development (S. Fork Toutle)	19,620	600	23,000

*Estimated at .31 smolts/M^2 and 10% smolt/adult survival.

Catch: Escapement	7:1	40.25:5.75 (Dollar Creek)
64% Commercial		26 X $8.98 = $233
36% Sport		14 X $107 = $1,498
		$1,731

Steelhead

Stream	Area (M^2)	Adults*	Benefit
Unnamed Creek (S.Fork)	5,886	14	$ 2,200
Wyant Creek	8,829	21	3,400
Thirteen Creek	19,620	47	7,500
Herrington Creek	4,414	11	1,700
Miners Creek	9,810	24	3,900
Devils Creek	39,241	94	15,000

*Estimated at .04 smolts/M^2 and 6% smolt/adult survival.

Catch: Escapement 3:1 10.5:3.5 (Unnamed Creek)
100% Sport 10.5 X $214 = $2,247

Cutthroat

Stream	Area (M^2)	Adults*	Benefit
Goat Creek	12,508	75	$ 1,800
Dollar Creek	1,472	9	216
Disappointment Creek	613	4	94
Herrington Creek	4,414	27	648
Tributary opposite Trouble Creek	1,104	7	166
Johnson Creek	981	6	$ 144
Wyant Creek	8,829	53	1,260
Outlet Creek	49,052	294	7,056
Miners Creek	9,810	59	1,404
Unnamed Tributary near Tower Rd.	491	3	72
Shultz Creek	11,733	70	1,656
Elk Creek	11,733	70	1,656
Devils Creek	39,241	235	5,616
Thirteen Creek	19,620	118	2,808
Side Channel-Development (S.Fork Toutle)	19,620	118	2,808

*Estimated at .06 smolts/M^2 and 10% smolt/adult survival.

Catch: Escapement 2:1 50:25 (Goat Creek)
100% Sport 50 X $36 = $1,800

Appendix II. Instream Habitat Improvements and Associated Costs

Root wad placement		$125/root wad
Debris removal	(Miners Creek)	$10,000/mile
	(Goat Creek)	20,000
Blasting	(Devils Creek)	5,000
	(Elk Creek)	7,000
Ladder	(Miners Creek)	25,000
	(Thirteen Creek)	8,000
	(Wyant Creek)	25,000
	(Outlet Creek)	25,000
Excavation of side channels	(S.Fork)	15,000
Riprap	(S.Fork)	19,200
Culvert installation	(S.Fork)	1,000/culvert

Operation and maintenance costs (O&M) are estimated at 10% of total cost. For improvements such as riprapping and excavation, there are no O&M costs. Blasting, laddering, root wad placement, debris removal, and culvert repair and/or installation would require maintenance on an annual basis. O&M would essentially be replacement of root wads when needed, ladder and culvert maintenance (removal of debris, yearly to biannual inspections, etc.), and stream inspection to determine need for additional debris removal. It is estimated that some small amount of debris removal would be necessary on an annual basis. Blasting, laddering, and culvert repair would be accomplished prior to any other improvements on a particular stream. In the case of the side channel improvements on the South Fork Toutle, the excavation, riprapping, and culvert placement would all occur prior to the placement of root wads. Any revegetation would probably occur simultaneously with instream debris placement.

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Division of Ecological Services
Portland Field Office
727 N. E. 24th Avenue
Portland, Oregon 97232

Reference NE:mm

September 30, 1985

Colonel Gary R. Lord, District Engineer
Portland District, Corps of Engineers
P. O. Box 2946
Portland, Oregon 97208

Re: NPPPL-FW

Dear Colonel Lord:

We have reviewed the draft information furnished us on August 29, 1985 regarding the dredging plan alternative as a solution to the long-term sediment control actions for the Toutle, Cowlitz, and Columbia Rivers. This dredging plan addresses only average annual deposition. We are concerned that no consideration is given for additional amounts of material from eruptive or storm events.

The general idea appears to be to dredge in the Toutle River at LT-1, LT-3, SF-1, and NF-1 until the disposal sites are no longer economical to use. This is expected to occur in about 10 years. After that, starting in 1997, and until the project ends, dredging and disposal will occur in the Cowlitz River. Based on sediment deposition to date, 80 percent of the sediment load in the Cowlitz is deposited between RM 10 and 20, and only 20 percent in the lower 10 miles. The plan calls for continuous dredging in the upper Cowlitz. The lower 10 miles would be dredged in 1997 and 1998. Dredging would then occur every other year until 2010, when it would be on a 3-year cycle. No dredging is anticipated in the Columbia River.

In the limited time available, we were not able to analyze the dredging information in any great detail. The following is a rough comparison of the dredging and single retention structure (SRS) alternatives for the Toutle and Cowlitz Rivers.

TOUTLE RIVER

DREDGING ALTERNATIVE

The following table provides a summary of estimated mitigation costs for three categories of disposal sites. A description of the categories is in our Continued Planning Aid Letter (CPAL) of August 2, 1985.

Table 1. Estimated Mitigation Costs for the Toutle River, Dredging Alternative (1986 - 2035) 1/

	Categories					
	1		2		3	
	Acres	Mit. Cost	Acres	Mit. Cost	Acres	Mit. Cost
NF/SF	948.1	$5,688,600	70.6	$ 941,098	119.1	$2,060,430
Total Acres Impacted: 1,137.8 --- Mitigation Costs: $8,690,128						
LT-1	510.1	$3,060,600	127	$1,679,575	35	$ 581,100
Total Acres Impacted: 672.1 --- Mitigation Costs: $5,321,275						
LT-3	853.1	$5,118,600	328.5	$4,459,387	314	$5,652,000
Total Acres Impacted: 1,495.6 --- Mitigation Costs: $10,623,247						
TOTAL ACRES IMPACTED: 3,305.5 --- MITIGATION COSTS: $24,634,650						

1/ Mitigation costs based upon Table 3 in the August 2, 1985, CPAL.

Advantages:

1. Fish passage problems are eliminated with this alternative, except for short periods during dredging.

2. Habitat throughout the watershed can be used by anadromous fish; natural recovery can proceed unimpeded.

3. Dredging provides more flexibility. The SRS is a permanent structure which would not permit major adjustments if the sediment budget changes significantly over time. If sediment loads decrease, the dredging alternative allows adjustments to be made to reduce acres affected by disposal, reduce mitigation costs, and alter disposal locations.

4. Fish mitigation costs are reduced with this alternative due to elimination of fish passage facilities.

5. Fewer acres (830) of wildlife habitat are impacted by this alternative in the Toutle River.

6. Scope of monitoring plan and associated costs would be reduced significantly.

Disadvantages

1. We have had very little success in directing spoil placement in the past to less sensitive fish and wildlife habitats. Judging by the past, achieving our mitigation goals with the SRS Alternative could be more successful.

2. Mitigation costs are greater under this alternative.

SRS ALTERNATIVE

The following table provides a summary of estimated mitigation costs for two disposal sites and other mitigation activities along the Toutle River.

Table 2. Estimated Mitigation Costs for Toutle River SRS Alternative (1986 - 2035)

	Categories					
	1		2		3	
	Acres	Mit. Cost	Acres	Mit. Cost	Acres	Mit. Cost
LT-1	287	$1,722,000	127	$1,679,575	9	$ 128,700
Total Acres Impacted: 423 --- Mitigation Cost: $3,530,275						
LT-3	542	$3,252,000	255	$3,461,625	314	$5,652,000
Total Acres Impacted: 1,111 --- Mitigation Cost: $12,365,625						

SRS (Additional project measures which offset wildlife habitat losses.)

Fertilizing and seeding of sediment inundation zone (3,000 acres).

Maintenance of vegetation on lands above sediment inundation zone to offset habitats inundated with sediment (4,448 acres).

Riparian Improvements (joint fish and wildlife benefits) (170 acres to be planted, mitigation cost $22,000).

TOTAL ACRES IMPACTED: 4,134 --- MITIGATION COST: $15,917,900

Advantages

1. Agencies may be closer to agreement on mitigation requirements for SRS than the dredging alternative.

2. Project impacts are concentrated in upper watershed instead of lower watershed where volcanic impacts were not as great.

3. Mitigation costs are lower under this alternative.

Disadvantages

1. Although funds have been allocated to provide fish passage, it is uncertain whether effective passage can actually be designed. This has the potential to result in significant losses of fish habitat.

2. Cost of fish passage and fish habitat mitigation is great.

3. Results in a permanent, large structure in the watershed with associated future management problems, beyond the 50 year project life (e.g., fish passage will always be a problem).

4. Reduced flexibility to decrease project impacts if sediment budget decreases.

5. Need for an extensive and expensive monitoring plan.

6. Approximately 830 additional acres of wildlife habitat are affected by this alternative in the Toutle Basin.

COWLITZ RIVER

At first glance, the large number of sites used each year dredging occurs in the Cowlitz would make this alternative very expensive in terms of mitigation costs. For example, in 1986 dredging of 2.61 million cubic yards (mcy) is proposed for the Cowlitz River. The material will be placed in 25 different disposal sites. Assuming a worst case situation (i.e. all of each site is used) and by using the cost figures for mitigation planning as presented in our continued Planning Aid Letter of August 2, 1985, the mitigation costs are as follows:

Table 3. Mitigation Costs, 1986 Cowlitz River Dredging Only

	DISPOSAL SITES	MITIGATION SITES	
	Cat. 1, 2, & 3	Cat. 2	Cat. 3
Acreage	1,021	360	97.5
Land Acquisition	--	$1,170,000	316,875
Development	$3,063,000	1,080,000	438,750
O&M	3,063,000	1,080,000	292,500
Long Term Maint.	--	14,440	9,750
Total	$6,126,000	$3,344,440	$1,057,875
Grand Total			$10,528,315

For the period 1997-2036, an additional 1,303 acres of land will be used as disposal sites, requiring 618 acres of mitigation lands. This does not take into account that the sites used in 1986 will have recovered some wildlife values before they are used again, a minimum of 10 years later.

In the best possible case, many of these mitigation costs could be minimized by not using portions of sites that include Category 2 and 3 habitat, or avoiding entirely high value sites such as 3a, c, d, 4a, 13b, 20d, and 32a. Selective and judicious use of sites and disposal strategies would also minimize habitat losses and, therefore, mitigation needs. However, it is quite uncertain that this could be accomplished under present construction procedures.

We have not had an opportunity to see exact locations or inspect the levee improvement sites described in your August 29, 1985 letter. It appears, however, that the 100-year flood event plan would have a minimal effect on fish and wildlife habitat. The 500-year flood event plan could have some minor effects on wildlife habitat on the Coweeman River Levee. The 500-year + 4' flood event plan would have the most impacts on wildlife habitat, but more information is needed before the impacts can be identified.

SUMMARY

The major deficiency with the dredging alternative is lack of provision for eruptive or storm events. A large event, or two smaller ones back to back could completely fill disposal sites in several reaches of the Cowlitz and/or Toutle Rivers and drastically alter the proposed disposal plan.

Due to all the uncertainties involved in minimizing the impacts of the dredging alternative on wetlands and wildlife habitat, the very costly needs for mitigation, and the lack of provision for storm and eruptive

events, we believe the SRS alternative should continue to be viewed as the preferred plan for controlling sediments. However, in the event that dredging is analyzed further or becomes the selected plan, substantial efforts should be made to identify and implement mitigation measures to offset dredging impacts on fish and wildlife resources.

Sincerely,

Russell D. Peterson

Russell D. Peterson
Field Supervisor

cc:
ES, Olympia